REPORT TO THE SPACE SCIENCE BOARD

on the

SPACE SCIENCE

and

APPLICATIONS PROGRAMS

November 1966

NASA HEADQUARTERS WASHINGTON, D.C. 20546

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PAST ACCOMPLISHMENTS

PAST ACCOMPLISHMENTS

The following is a list of the successful major satellite and space probe firings that have been carried out in connection with the OSSA program since the creation of NASA in 1958:

1958

Pioneer I	Magnetic field, radiation belts
Pioneer II	Magnetic field, radiation belts, cosmic rays
Pioneer III	Radiation belts, cosmic rays

1959

Vanguard II	Cloud cover
Pioneer IV	Radiation belts, cosmic rays
Explorer VI	Magnetic field, radiation belts
Vanguard III	Magnetic field
Explorer VII	Radiation belts, cosmic rays, thermal radiation, micrometeors

1960

Pioneer V	Magnetic field, cosmic rays
TIROS I	Cloud cover
Echo I	Air density, passive communications
Explorer VIII	Ionosphere, micrometeors
TIROS II	Cloud cover, thermal radiation

1961

Explorer IX	Air density
Explorer X	Magnetic field, plasma
Explorer XI	Gamma radiation
TIROS III	Cloud cover, thermal radiation
Explorer XII	Magnetic field, radiation belts, cosmic rays
Explorer XIII	Micrometeoroids

1962

TIROS IV	Cloud cover, thermal radiation
OSO I	Electromagnetic radiation from Sun
Ariel I	First international satellite (United Kingdom) Ionosphere, radiation
TIROS V	Cloud cover
Telstar I	Active communications
Mariner II	Energetic particles and magnetic fields, cosmic dust, Venus IR and microwave radiation
TIROS VI	Cloud cover

Alouette I	International satellite (Canada) Ionosphere topside sounding, radio noise, cosmic rays
Explorer XIV	Energetic particles, magnetic field, cosmic rays
Explorer XV	Radiation belts
ANNA 1-B	Geodesy
Relay I	Active communications, radiation
Explorer XVI	Micrometeoroids, radiation

1963

Explorer XVII	Atmosphere structure
Telstar II	Active communications
TIROS VII	Cloud cover
Syncom II	Active communications, synchronous orbit
Explorer XVIII	Interplanetary Explorer, particles and fields, solar wind shock wave
Centaur II	First successful development flight, instrumented with sensors and telemetry
Explorer XIX	Air density
TIROS VIII	Cloud cover, Automatic Picture Transmission (APT) system for real-time readout of local cloud pictures

1964

Relay II	Active communications, low altitude orbit
Echo II	Passive communications
Ariel II	US-UK satellite, ozone distribution sampling, galactic radio noise
Centaur III	Vehicle development. All six primary objectives attained.
Ranger VII	Lunar photography (4316 high resolution TV pictures)
Syncom III	Active communications, synchronous orbit
Explorer XX	Ionospheric measurement by topside sounding
Nimbus I	Global cloud cover, APT for local read-out, HRIR for nighttime cloud pictures
Explorer XXII	Ionospheric measurement, first use of ground based laser for tracking and geodetic studies.
Explorer XXIII	Meteoroid penetration
Explorer XXIV*	Upper air density and temperature measurements
Explorer XXV*	Corpuscular radiation and charged particle measurements
Mariner IV	Flyby of Mars in mid-1965 provided data on Martian atmosphere and surface, magnetic fields, cosmic dust
Centaur IV	Carried mass-model of Surveyor spacecraft
San Marco I	Atmospheric physics, Italian payload, Italian launched.
Explorer XXVI	Radiation belts

* First NASA dual payload launch using single booster.

1965

TIROS IX	First TIROS cartwheel configuration for increased cloud coverage data
OSO II	Solar physics
Ranger VIII	Lunar photography (7,137 pictures)
Ranger IX	Lunar photography (5,814 pictures)
Gemini III	Synoptic terrain photography; synergistic effects on blood
Early Bird I	Communications (for Comsat Corporation)
Explorer XXVII	Geodesy, laser tracking, ionospheric measurements
Explorer XXVIII	Interplanetary Explorer, particles and fields
Gemini IV	Synoptic terrain and weather photography
TIROS X	Meteorology, cloud cover photography, first Weather-Bureau-funded spacecraft
Scout Evaluation	Vehicle development, evaluation of Castor II second stage, orbited U.S. Army SECOR geodetic satellite
Centaur VI	Carried Surveyor dynamic model into simulated lunar transfer trajectory
Gemini V	Cloud top spectrometry; visual acuity; zodiacal light, synoptic terrain and weather photography
OGO II	Interdisciplinary experiments, emphasizing atmospheric studies and World Magnetic Survey
Gemini VI	Synoptic terrain and weather photography
Explorer XXIX	Geodetic Explorer, define Earth's gravity field
Explorer XXX	Solar physics, Navy payload, part of IQSY program
Alouette II**	Swept frequency topside sounder. International satellite (Canada)
Explorer XXXI**	Ionospheric measurements
Gemini VII	Visual acuity, synoptic terrain and weather photography
French I	Ion distribution in magnetosphere, French payload
Pioneer VI	Study interplanetary phenomena in ciscytherean space

1966

ESSA I	Meteorology - initiated TIROS Operational Satellite (TOS) system
ESSA II	Operational meteorological satellite. Advanced version of cartwheel configuration
Gemini VIII	Frog egg growth, synoptic terrain and weather photography, Agena micrometeorite collection
Nimbus II	Earth-oriented R&D meteorological satellite. Advanced Vidicon Camera System (AVCS), Automatic Picture Transmission (APT), High Resolution Infrared Radiometer (HRIR), Medium Resolution Infrared Radiometer (MRIR). APT modified to read-out HRIR

** Dual payload launch using single booster.

Gemini IX	Zodiacal light, airglow horizon, and synoptic terrain and weather photography; and Agena and Gemini micrometeorite collections
Explorer XXXII	Aeronomy
Surveyor I	Soft lunar landing; bearing strength of lunar surface; surface particle detail; TV photography
OGO III	Interdisciplinary studies. First three axis stabilized spacecraft in highly elliptical Earth orbit.
Pageos I	Geodesy - establish world-wide triangulation network by optical sightings
Explorer XXXIII	Particles and Fields - interplanetary studies
Gemini X	Zodiacal light, and synoptic terrain and weather photography; Agena micrometeorite collections; UV astronomical camera; and ion wake measurements
Lunar Orbiter I	Photographed potential lunar sites for Apollo landings and far side of Moon. First view of the Earth from the vicinity of the Moon.
Pioneer VII	Interplanetary probe to the outside of the orbit of the Earth.
Gemini XI	Synergistic effects on blood and Neurospora; airglow horizon, and synoptic terrain and weather photography; nuclear emulsions; UV astronomical camera; ion wake measurements; image/orthicon photographs
ESSA III	Operational meteorological satellite - advanced cart-wheel design placed in nearly polar Sun synchronous orbit - first Advanced Vidicon Camera System (AVCS) in TIROS/TOS series; also carried IR Earth heat balance sensor - first Delta vehicle launched from Western Test Range
Lunar Orbiter II	Lunar Photography
Centaur IX	Fully qualified 2-burn capability; completes Centaur development program - Injected Surveyor mass-model into simulated lunar transfer orbit
Gemini XII	Frog egg growth; airglow horizon, and synoptic terrain and weather photography; Agena and Gemini micro-meteorite collections; UV astronomical camera; libration region photographs; and sodium vapor clouds.

OSSA PLANNED

FLIGHT SCHEDULE

OSSA PLANNED FLIGHT SCHEDULE

PROGRAM/PROJECT	LAUNCH VEHICLE	CY 1966 4 QTR	CY 1967 1	CY 1967 2	CY 1967 3	CY 1967 4	CY 1968 1	CY 1968 2	CY 1968 3	CY 1968 4
PHYSICS AND ASTRONOMY										
OSO	D		X	X			X			X
OAO	AAG							X		
OGO	AAG, TAT			X	X			X		
EXPLORERS	SC, D, TAD		3X	3X	4X	5X		2X	2X	X
PIONEER	TAD					X	X		X	
LUNAR AND PLANETARY										
LUNAR ORBITER	AAG	X	X	X	X					
SURVEYOR	AC		X	X	X	2X				
MARINER (VENUS)	AAG			X						
BIOSCIENCE										
BIOSATELLITE	D, TAD	X	X	S*	S*		S*			
SPACE APPLICATIONS										
TIROS	TAD									X
NIMBUS	TAT					X				
ATS	AAG	X		X		X		X		X
GEOS EXPLORER	D				X					
LAUNCH VEHICLES										
CENTAUR DEVELOPMENT	AC	X								

* S indicates schedule under study

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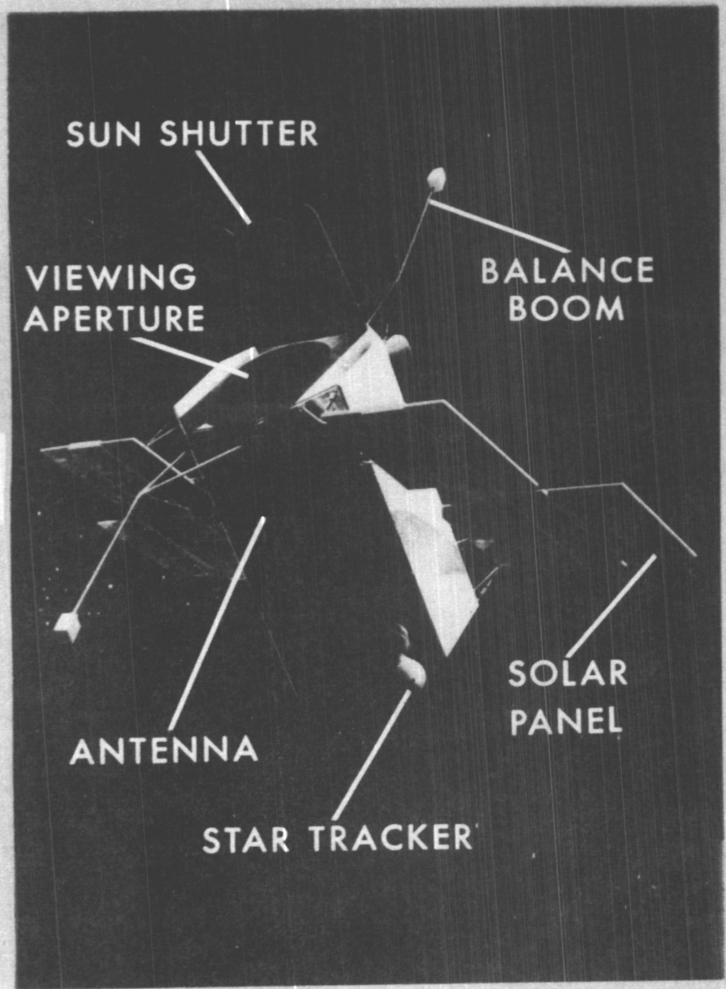
PHYSICS AND ASTRONOMY

ORBITING ASTRONOMICAL OBSERVATORY



GROSS WEIGHT	- 4000 LBS.
INSTRUMENT WEIGHT	- 1000 LBS.
INVESTIGATIONS	- SEVERAL/SPACECRAFT
STABILIZATION	- ACTIVE 3-AXIS
DESIGN LIFE	- ONE YEAR
LAUNCH VEHICLE	- ATLAS-AGENA
ORBIT	- CIRCULAR 500 MI. INCLINATION 35°
STATUS	- FIRST OAO - 1966 - SECOND OAO - 1968

NASA SD63-1450
Rev. 11-17-66

ORBITING ASTRONOMICAL OBSERVATORY

The Orbiting Astronomical Observatories (OAO) are designed to provide an opportunity to explore those regions of the spectrum that are inaccessible to ground-based instrumentation because of atmospheric absorption. The OAO is a precisely-stabilized satellite designed to accommodate various types of astronomical observing equipment. The primary experiments for the first four observatories are concerned with stellar astronomy in the ultraviolet range (800-4000A). The observatories will be placed in nearly circular orbits at an altitude of 500 miles with an inclination of 35 degrees.

The basic OAO structure is tubular with an octagonal cross-section. The total weight of the spacecraft is about 4000 pounds, of which 1000 pounds is allocated to the experimental equipment. An average power of 400 watts is available, supplied by silicon solar cells and nickel-cadmium storage batteries. About 30 watts average and 60 watts peak is available for each investigation. Provision is made for data storage and for commands to the spacecraft.

The stabilization and control system consists of star trackers, Sun trackers, inertial wheels, and gas jets. The spacecraft is designed to point in any direction with an accuracy of 1 minute of arc during the observation of an individual star. The pointing accuracy can be increased to 0.1 second of arc using sensors associated with the experiment instrumentation. The attitude control system performs three functions:

1. To stabilize the OAO following booster separation and to establish the required attitude.

2. To slew the satellite to the attitudes required to meet the scientific objectives of the mission.

3. To maintain a given attitude for long periods of time.

It is expected that all OAOs will have a limited amount of payload capacity for secondary investigations in addition to the primary investigations. OAO-A1 was launched on April 8, 1966, and was then designated OAO-I. It achieved orbit and stabilization but on the second day a failure in the power subsystem caused the Observatory to fail before any scientific data had been secured. The next OAO flight is scheduled for 1968.

OAO-B

1. Absolute spectrophotometry measurements of stars and nebulae (1000 to 4000A).

A. Boggess
Goddard Space Flight Center

OAO-A2

1. Four high-resolution telescopes (Schwarzschild cameras) with UV-sensitive Uvicon image-forming devices will survey the sky in the UV ranges, 1200-1550A, 1375-1625A, 1800-2800A, and 2350-2850A; will record the brightness of hot stars, primarily spectral type A and earlier; and will map the form and brightness characteristics of faint nebulae.

F. Whipple and R. Davis
Smithsonian Astrophysical Observatory

2. Stellar broad-band photometry between 900A and 3000A; measurements of emission characteristics of diffuse nebulae; extension of opacity measurements of the interstellar medium into the ultraviolet. Will use multicolor filter photometers with 8- and 16-inch telescopes and two auxiliary spectrometers.

A. D. Code
University of Wisconsin

OAO-C

1. Study quantitative absorption spectra of interstellar gas in the far UV (800-3000A with 0.1A resolution); composition and physical condition of the clouds of interstellar gas and dust. A cassegrain reflecting telescope, concave grating spectrometer, and photocells will be used.

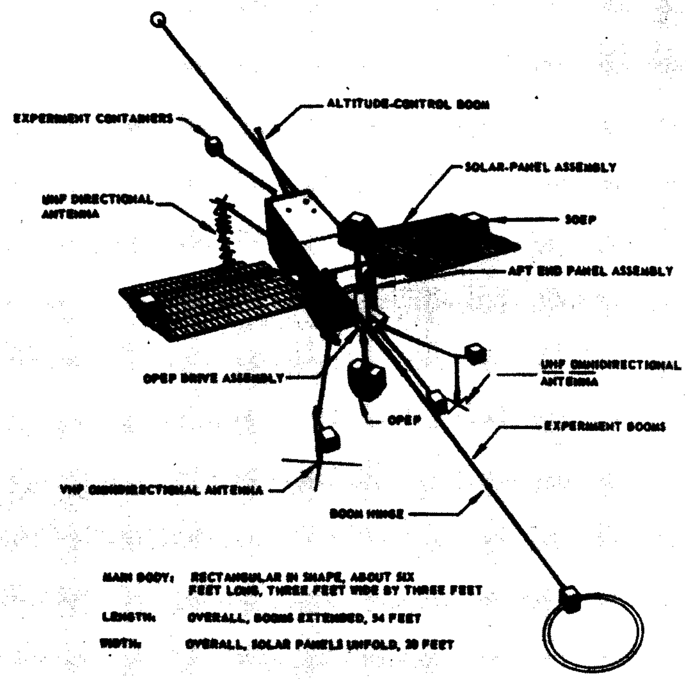
L. Spitzer
Princeton University

2. Study X-ray emissions of stars and nebulae (3-12A, 8-18A, and 44-60A); using three paraboloidal reflectors, three photon detectors, and three gas counters. Search for interstellar absorption in the range 44-60A.

R. L. F. Boyd
University College London

ORBITING GEOPHYSICAL OBSERVATORY (OGO)

OGO FULLY DEPLOYED IN ORBIT



GROSS WEIGHT	1200 LBS.
INSTRUMENT WEIGHT	260 LBS.
INVESTIGATIONS	UP TO 30/SPACECRAFT
POWER	250 WATTS (AVERAGE)
STABILIZATION	ACTIVE 3-AXIS
DESIGN LIFE	ONE YEAR 0.7 PROBABILITY
LAUNCH VEHICLES	ATLAS-AGENA TAT-AGENA
ORBITS	HIGHLY ELLIPTICAL INCLINED ORBIT; NEARLY CIRCULAR POLAR ORBIT
STATUS	FIRST OGO 1964 FOURTH OGO 1967

NASA HQ SP65-16317
Rev. 11-17-66

ORBITING GEOPHYSICAL OBSERVATORIES

The Orbiting Geophysical Observatories (OGO) are a series of standardized spacecraft incorporating active three-axis stabilization and accommodating up to thirty scientific investigations to make correlative studies.

Three Orbiting Geophysical Observatories have been launched: two of these (OGO-I and OGO-III) into highly elliptical inclined orbits extending beyond the magnetosphere and one (OGO-II) into a low altitude approximately polar orbit. Additional missions are planned (OGO-D, E and F) in 1967 and 1968.

The OGO-D and F missions will be placed into polar orbits with apogees of 500 nm and perigees of about 200 nm to study the interrelationships of particle activity with auroral and airglow phenomena, the magnitude and fluctuations of the geomagnetic field, the neutral and ionic composition of the upper atmosphere, and the electromagnetic energy sources contributing to ionization and atmospheric heating. A very important objective of these missions is the detailed study of the near-Earth environment during the period of increasing solar activity and at solar maximum.

The orbit for the OGO-E mission will have an apogee of 80,000 nm and a perigee of 150 nm. This mission carries 24 experiments which, as an entirety, will investigate particles having energies ranging from a few electron volts to ten billion electron volts. This includes the total spectrum of significant particle populations within the magnetosphere and the solar plasma. Associated with these investigations are detailed studies of electric and magnetic fields, very low frequency radio noise, galactic emissions, and other electromagnetic emissions in the ultraviolet and X-ray bands.

OGO-I was launched on September 4, 1964 and continues to operate after two years in orbit with about half of the original twenty experiments still providing very useful data. OGO-II was launched on October 14, 1965. Following a short period of three-axis stabilization and the premature depletion of control gas, OGO-II entered a spin-stabilized attitude which permits periodic operation during times of favorable solar aspect. The most recent mission, OGO-III, was launched June 7, 1966 and performed flawlessly for 46 days. Failure of a component in the attitude control system necessitated activation of a secondary spin stabilization mode. OGO-III has achieved all mission objectives; however, continuing operation for an extended period is expected.

The OGO spacecraft weighs about 1200 pounds, including approximately 260 pounds which are available for investigations. The spacecraft mainbody is approximately 31 inches by 33 inches by 67 inches and contains portions of the spacecraft subsystems and space for scientific instrumentation. The power supply system consists of solar cell panels, chemical batteries, and a charge control system. A maximum of 500 watts and an average of 250 watts of power are available. Maximum power allocated to scientific investigations is 80 watts and the average power is 50 watts. Angular orientation of the spacecraft is accomplished through torques developed by motor-driven inertial flywheels and by gas jets. Deviations of the spacecraft from the sun axis are sensed by solar cells; deviations from the Earth's local vertical are determined by horizon scanners. Thermal control is accomplished by use of radiation shields and louvers. The data processing and communications system accepts ground commands to program investigations, to vary transmission rates, and to apportion information bits to the data generated by the investigations and by vehicle performance parameters. Storage of 84 million bits of data is possible by using two magnetic tape recorders. Two redundant wideband telemetry transmitters in the spacecraft are capable of sending scientific and spacecraft engineering data back to Earth, either in real time on command, or from storage.

Spacecraft design, development and fabrication through test and evaluation are being accomplished under contract with TRW Systems, Los Angeles, California.

The following are the lists of scientific investigations and investigators for OGOs D, E and F.

OGO-D

1. Antenna (60 feet) to determine brightness distribution of galactic emissions at 2.5 Mc.

   F. T. Haddock
   University of Michigan

2. Toroidal antenna to observe VLF emissions (15 cps to 100 kc) for study of electrostatic and electromagnetic phenomena.

   R. A. Helliwell
   Stanford University

   L. H. Rorden
   SRI

3. Dipole antenna (10 feet) to detect VLF terrestrial and other emissions at 0.5 - 18 Kc.

   M. G. Morgan
   Dartmouth College

   T. Laaspere
   Dartmouth College

4. Triaxial search coil magnetometer to measure magnetic field fluctuations (frequency range 0.01-1,000 cps).

   E. J. Smith
   JPL

   R. E. Holzer
   UCLA

5. Rubidium vapor magnetometer for World Magnetic Survey

   J. C. Cain
   GSFC

   L. R. Langel
   GSFC

6. Ionization chamber for measurement of cosmic ray and solar flare particle intensity; protons above 10 Mev; alpha particles above 40 Mev; and electrons above 0.5 Mev.

   H. R. Anderson
   Rice University

   H. V. Neher
   California Inst. of Technology

7. Scintillation telescopes for determination of energy and intensity of protons (0.5 to 40 Mev) and alpha particles (2-160 Mev).

J. A. Simpson
University of Chicago

E. C. Stone
University of Chicago

C. Y. Fan
University of Chicago

8. Modified Cerenkov detector to observe energy spectrum and charged particle composition of galactic and solar cosmic rays.

W. R. Webber
University of Minn.

9. Electrostatic analyzer and silicon detectors to observe trapped protons (0.25 to 20 Mev) and trapped alpha particles (0.40 - 200 Mev). GM tube for integral flux of electrons above 40 kev.

J. A. Van Allen
University of Iowa

L. A. Frank
University of Iowa

S. M. Krimigis
University of Iowa

T. P. Armstrong
University of Iowa

T. A. Fritz
University of Iowa

10. Electrostatic analyzers for measurement of energy spectra and pitch angle distribution of protons and electrons (0.5 to 20 kev).

R. A. Hoffman
GSFC

D. S. Evans
GSFC

11. Photometric measurements of airglow and auroral emissions at 6,300 A 6,225 A , 5,890 A , 5577 A , 3,914 A , and 2,630 A .

J. Blamont
Univ. of Paris

E. I. Reed
GSFC

12. UV ion chambers for airglow studies in the Layman-Alpha, (1050 - 1350A) and the far UV (1230 - 1350A) regions.

P. W. Mange
NRL

T. A. Chubb
NRL

H. Friedman
NRL

13. UV spectrometer for airglow measurements between 1100 A and 3400 A.

C. A. Barth
Univ. of Colorado

L. Wallace
Kitt Peak National Observatory

E. F. Mackey
Packard-Bell Electronics

14. Paul Massenfilter spectrometer for neutral particle and ion composition in the mass ranges 0-6 AMU and 0-40 AMU.

L. M. Jones
Univ. of Michigan

E. Schaefer
Univ. of Michigan

15. Bennett RF ion mass spectrometer for mass ranges of 1-6 AMU and 7-45 AMU.

H. A. Taylor, Jr.
GSFC

H. C. Brinton
GSFC

16. Bayard-Alpert ionization gauge to measure density of neutral particles.

G. P. Newton
GSFC

17. Detectors to measure spatial density, mass distribution, velocity and charge of dust particles.

C. S. Nilsson
GSFC

18. Combined retarding-potential analyzer to study ionospheric charged particles and solar UV radiation.

J. Donley
GSFC

R. E. Bourdeau
GSFC

19. Four ionization chambers to determine time variations in solar X-ray emission in the 0.5-3A, 2-8A, 8-16A, and 44-60A bands.

R. W. Kreplin
NRL

T. A. Chubb
NRL

H. Friedman
NRL

20. Scanning spectrometer to monitor solar emission in the 170-1700A regions.

H. E. Hinteregger
AFCRL

1. Spherical retarding potential analyzer for electron density (10 to 10^4 per cm^3) and temperature measurements (500 to 10,000° K).

   R. L. F. Boyd
   Univ. College London

   A. P. Willmore
   Univ. College London

2. Planar retarding potential analyzer to measure density and temperature of ions and electrons (below 100 ev..

   G. P. Serbu
   GSFC

   E. J. Maier
   GSFC

3. Spherical retarding potential analyzers (A. C. mode) for density and temperature of charged particles of thermal energy (10 to 6 x 10^6 per cm^3; 700 to 4,000° K); flux and energy spectrum (electron and protons) in range 0 to 2 Kev.

   R. C. Sagalyn
   AFCRL

   M. Smiddy
   AFCRL

4. Three electrostatic analyzers to measure distribution of electrons (0-15 Kev).

   K. W. Ogilvie
   GSFC

   T. D. Wilkerson
   Univ. of Md.

5. Two electrostatic analyzers and Faraday cups to measure energetic plasma (3 ev to 16 Kev) with good energy and time resolution.

   C. W. Snyder
   JPL

   M. Neugebauer
   JPL

   J. L. Lawrence, Jr.
   JPL

6. Cylindrical electrostatic analyzer to study distribution of low energy electrons and protons (0.10 to 50 Kev). GM tube for electron flux above 40 Kev.

L. A. Frank
University of Iowa

W. A. Whelpley
University of Iowa

J. A. Van Allen
University of Iowa

7. Magnetic electron spectrometer and proton telescope for energetic particle measurements: electrons (50 Kev to 3 Mev); protons (100 Kev to 50 Mev).

D'Arcy
Lawrence Radiation Lab.

L. Mann
Lawrence Radiation Lab.

H. West
Lawrence Radiation Lab.

8. Scintillation telescope to study low energy electrons (0.1 to 8 Mev), positrons (0.5 to 8.0 Mev), protons (2 to 70 Mev), and gamma rays (50 to 700 Kev).

T. L. Cline
GSFC

9. Geiger-Mueller tube and scintillation detectors to study solar cosmic rays; X-rays (5 to 90 Kev); protons (8 to 300 Mev); electrons (20-40 Kev, 40-80 Kev, 300-400 Kev); alpha particles (30 to 1,200 Mev).

K. A. Anderson
University of California, Berkeley

H. Mark
University of California, Berkeley

10. Solid state detectors to determine the abundance and differential energy spectrum of primary cosmic rays (2-50 Mev/nucleon) and to search for heavy nuclei from solar flares.

J. A. Simpson
University of Chicago

11. Three counter telescopes (low, medium and high energy) for resolution of low energy galactic cosmic rays and solar proton events; protons (0.4 to 1,200 Mev); electrons (1 to 10 Mev); alpha particles (2 to 1,200 Mev).

F. B. McDonald, G. H. Ludwig, D. E. Hagge, V. H. Balasubrahmanyan
GSFC

12. Spark chamber to measure direction of incidence of primary cosmic rays.

G. W. Hutchinson
U. of Southampton

D. Ramsden
U. of Southampton

R. D. Wills
U. of Southampton

13. Particle telescope to determine flux and energy spectrum of cosmic ray electrons (20 to 100 Mev).

P. Meyer
U. of Chicago

C. Y. Fan
U. of Chicago

14. Counter telescope for the measurement of the absolute flux and energy spectrum of energetic galactic cosmic ray electrons (0.5 to 10 Bev); protons (20 to 100 Bev); and gamma rays (above 500 Mev).

A. H. Wapstra
Netherlands Inst. of Nuclear Physics Research

Y. Tanaka
Working Group, Cosmic Radiation, Netherlands

M. N. Lund
Working Group, Cosmic Radiation, Netherlands

Ir A. Scheepmaker
Working Group, Cosmic Radiation, Netherlands

B. M. Swanenberg
Working Group, Cosmic Radiation, Netherlands

15. Triaxial fluxgate magnetometer and six solid state detectors for correlation of trapped particle characteristics with hydromagnetic waves.

P. J. Coleman
UCLA

T. A. Farley
UCLA

D. L. Judge
U. of S. Calif. & TRW Systems

16. Triaxial fluxgate and rubidium vapor magnetometers for vector and scalar magnetic field measurements (1 to 30,000 gamma).

J. P. Heppner
GSFC

T. L. Skillman
GSFC

B. G. Ledley
GSFC

M. Campbell
GSFC

M. Sugiura
GSFC

17. Triaxial search coil magnetometer to study magnetic field fluctuations (frequency range of 0.01 to 1,000 cps).

E. J. Smith
JPL

R. E. Holzer
UCLA

18. Orthogonal systems of electric and magnetic field antennas to detect and measure electric plasma oscillations and electromagnetic waves (300 cps to 20 Kc).

G. M. Crook
TRW Systems

F. L. Scarf
TRW Systems

R. W. Fredricks
TRW Systems

19. Two 60-foot antennas and a differential electrometer to measure ambient magnetospheric electric fields.

T. L. Aggson
GSFC

J. P. Heppner
GSFC

N. C. Maynard
GSFC

20. UV photometers to measure radiation of neutral atomic oxygen (1304A) and hydrogen (1216A) in airglow.

C. A. Barth
U. of Colorado

J. B. Pearce
U. of Colorado

E. F. Mackey
Packard-Bell Electronics

21. Hydrogen cell to determine number density and temperature of hydrogen in the geocorona.

J. E. Blamont
Univ. of Paris

22. Proportional counter spectrometer to measure solar X-ray emissions in the 0.6-6.0A region.

R. W. Kreplin
NRL

T. A. Chubb
NRL

H. Friedman
NRL

23. Magnetic mass spectrometer to resolve the relative concentrations of H^+, H_2^+, He^+ and heavy ions.

G. W. Sharp
LMSC

T. J. Crowther
LMSC

24. Stepped frequency radiometer (60-foot dipole antenna) for observation of low frequency radio bursts and cosmic noise (50 Kc/s to 2 Mc/s).

F. T. Haddock
U. of Michigan

1. Gage to measure neutral atmospheric density in altitude range from 250 to 700 Km.

   G. W. Sharp, T. J. Crowther
   LMSC

2. Two Langmuir probes for measurement of the density and temperature of ambient charged particles.

   A. F. Nagy, L. H. Brace
   University of Michigan & GSFC

3. Planar ion trap to detect gradients in ion concentration, temperature and composition.

   W. B. Hanson, T. W. Flowerday
   GRSW

4. Quadrupole mass analyzer for study of neutral particle composition and scale height temperatures (1-44 AMU).

   C. A. Reber, D. Harpold
   Goddard Space Flight Center

   G. R. Carignan, D. R. Taeusch
   University of Michigan

5. Bennett r. f. spectrometer to measure positive ions (1-5 AMU and 5-45 AMU).

   R. Pickett, M. Pharo, H. A. Taylor
   Goddard Space Flight Center

6. Magnetic spectrometer and electron multiplier to study concentration of ionic species (1-34 AMU sweep and specific species).

   W. B. Hanson, T. W. Flowerday
   GRSW

7. Temperature-sensitive quartz crystal for total energy flux transfer, surface accommodation coefficients and atmospheric density studies.

   D. McKeown, H. R. Poppa
   General Dynamics/Convair

8. Scintillation crystal-proportional counter spectrometer to observe energetic solar X-ray emissions (0.15 to 6.2 A).

R. W. Kreplin, T. A. Chubb, H. Friedman, C. S. Bowyer
Naval Research Laboratory

9. Spectrophotometer to monitor intensity of solar radiation (160 to 1600 A).

D. E. Bedo, H. E. Hinteregger
AFCRL

10. Spectrograph to monitor intensity of solar radiation (1800 to 3100 A).

V. H. Regener
University of New Mexico

11. Hydrogen cell and gas-filled grating chamber to measure the intensity, distribution and character of Lyman-alpha radiation.

M. A. Clark, D. D. Elliott, P. H. Metzger
Aerospace

G. Münch
CIT

12. UV photometers to measure radiation of neutral atomic oxygen (1304 A) and hydrogen (1216 A) in airglow.

C. A. Barth, J. B. Pearce
University of Colorado

E. F. Mackey
Packard-Bell Electronics

13. Photometers and Fabry-Perot interferometer to detect atomic oxygen (6300 A) and N_2^+ (3914 A) emissions.

J. E. Blamont
University of Paris

14. Electrostatic analyzers to measure intensity and energy spectrum of electrons and protons (1-20 kev).

D. S. Evans, D. E. Stilwell
Goddard Space Flight Center

15. Seven detectors to determine intensity and pitch angle distribution of electrons (45 to 1200 kev).

T. A. Farley, M. C. Chapman
UCLA

16. Seven detectors to determine electron intensity in integral energy ranges greater than 100 kev, 300 kev, and 1 Mev.

D. J. Williams, J. H. Trainor
Goddard Space Flight Center

17. Plastic scintillator-moderated He^3 detector to determine the flux and energy spectra of albedo neutrons (2 to 8 Mev).

J. A. Lockwood, E. L. Chupp
University of New Hampshire

18. Telescope to measure intensity and energy distribution of solar cosmic rays: protons (5-80 Mev); alpha particles (20-150 Mev); and electrons above 250 kev.

A. J. Masley, P. R. Satterblom
Douglas Aircraft Company

19. Telescopes and a Cerenokow detector for differential energy spectra: protons and alpha particles (0.2 to 300 Mev/nucleon); electrons (1-1000 Mev) and flux of protons and alpha particles above 300 Mev/nucleon.

E. C. Stone, R. E. Vogt
CIT

20. Rubidium vapor magnetometer for World Magnetic Survey.

J. C. Cain, W. H. Farthing, R. A. Langel
Goddard Space Flight Center

21. Triaxial search coil magnetometer to measure natural magnetic field fluctuations (0.01 to 1000 cps).

E. J. Smith, R. E. Holzer
JPL UCLA

22. Two 60-foot antennas and differential electrometer to measure ambient magnetospheric electric fields.

T. L. Aggson, J. P. Heppner
Goddard Space Flight Center

239-359 O - 66 - 3

23. Three orthogonal loop antennas to detect magnetic and electric field components (10 cps to 30 kcs).

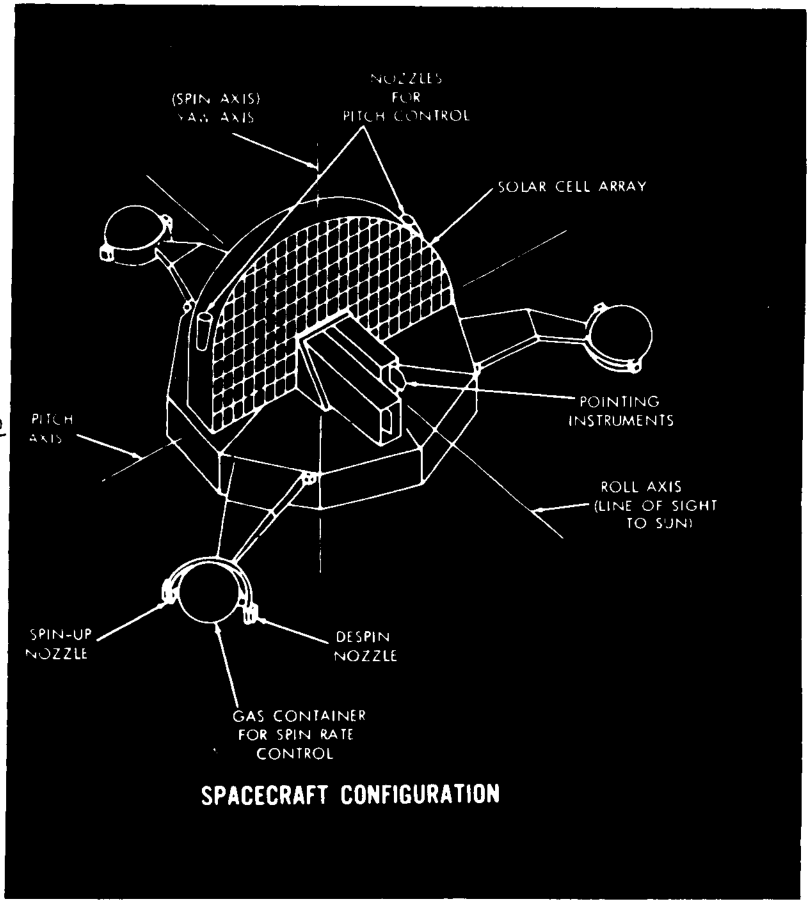
R. A. Helliwell, R. L. Smith
Stanford University

24. Two 60-foot antennas to investigate characteristics and propagation of electromagnetic energy in the whistler mode:

(0.1 - 20		200 cps bands near
20 - 40		200 kcs &
140 - 160	and	550 kcs)
280 - 300 kcs		

T. Laaspere, M. G. Morgan
Dartmouth College

ORBITING SOLAR OBSERVATORY



SPACECRAFT CONFIGURATION

GROSS WEIGHT	600 LBS.
INSTRUMENT WEIGHT	220 LBS.
EXPERIMENTS	7-9
POWER	30 WATTS (TYPICAL MAX. LOAD)
STABILIZATION	SPIN
DESIGN LIFE	6 MONTHS
LAUNCH VEHICLE	DELTA
ORBIT	NEAR-EARTH CIRCULAR ORBIT
STATUS	FIRST OSO 1962 FOURTH OSO 1967

NASA SG64-192
Rev. 11-17-66

ORBITING SOLAR OBSERVATORY

The Orbiting Solar Observatories (OSO) are a series of stabilized space platforms, designed to investigate solar phenomena from above the obscuring and distorting effects of the atmosphere. The spacecraft consists of a fan-shaped stabilized section connected by a shaft to a lower rotating wheel-like structure. The wheel contains nine, wedge-shaped compartments, five of which are available for scientific instrumentation, and the remaining four carry housekeeping equipment such as the telemetry system and batteries. The oriented portion of the spacecraft, which carries two compartments for scientific instrumentation, points continuously at the center of the Sun with an accuracy somewhat greater than one minute of arc. Provision for scanning the Sun with a resolution of one arc minute can be made available to the experimenters. Beginning with the OSO-G, investigators having experiments in the pointing section will also have the option of scanning any point within a forty arc-minute square centered on the Sun. The wheel investigations are, in general, sky mapping in character, and comparing radiation from the Sun to that in other portions of the sky. The OSO's will be launched from the Eastern Test Range (ETR) by Thor Delta vehicles and are intended to orbit the Earth in a circular orbit at an altitude of approximately 350 miles inclined 33 degrees to the equator.

On June 3, 1966, after 7 months of inoperation, OSO-II was commanded on. It operated successfully until all gas in the pitch bottle was expended, approximately ten days later. Data reduction and analysis is continuing and scientific papers are expected shortly utilizing data from OSO-II.

The fourth OSO will be launched early in 1967. Prior to launch it is designated OSO-E and it will carry the spares of the experiments which were flown on the unsuccessful OSO-C mission. The experiments and experimenters for three additional OSO's (D, F, and G) which have been selected as of October 1, 1966, are listed below. Proposals for OSO-H are being evaluated, and selection of the OSO-H payload is expected to be made before the end of 1966.

Pointing Section

1. Measurements of solar flare X-rays with crystal spectrometer to distinguish between emissions from a thermally-excited corona and from a relatively low temperature corona. (1 to 8A scan)

   H. Friedman, T. A. Chubb, R. Kreplin, J. Meekins
   Naval Research Laboratory

2. Determine solar UV spectrum (300-1300A) using normal incidence scanning spectrometer.

   L. Goldberg, E. M. Reeves, W. H. Parkinson
   Harvard College Observatory

3. Study of solar X-rays, 8-20A, above 20A, and below 8A, using a totally reflecting parabolic mirror and detector.

   R. Giacconi, F. Paolini
   American Science and Engineering, Inc.

Wheel Section

4. Survey of non-solar X-ray radiation (0.1-10A) using CsI and SrF_2 detectors.

   R. Giacconi, H. Gursky
   American Science and Engineering, Inc.

5. Distribution of total solar X-ray emission over a wide band, 1.2-3.6A, 3-9A, 6-18A, 44-55A and 44-70A using proportional counters and geiger counters.

   R. L. F. Boyd,
   University College, London

   K. A. Pounds
   University of Leicester

6. Measurements of charged particles (electrons >60 Kev and protons >2 Mev) using a crystal scintillator.

   J. A. Waggoner
   University of California, Livermore

7. Solar HeII resonance emission (303.8A) using a grating spectrometer and photomultipliers.

R. L. F. Boyd
University College, London

E. Stewardson
University of Leicester

8. Measurements of a solar X-ray radiation (8-16A, 2-8A, 0.5-3A, 0.1-1.6A)

T. A. Chubb, R. W. Kreplin, H. Friedman
Naval Research Laboratory

9. Lyman-alpha night sky glow observed with two ion chamber detectors.

P. W. Mange, T. A. Chubb, H. Friedman
Naval Research Laboratory

OSO-E

Pointing Section

1. Solar extreme ultraviolet flux measurements using a monochromator (250-1300A).

H. E. Hinteregger, L. Hall
Air Force Cambridge Research Laboratories

2. X-ray and UV solar spectrum measurements using spectrometer (1-400A) and X-ray ion chambers (1-8A and 10-20A).

W. M. Neupert, W. E. Behring, W. A. White
Goddard Space Flight Center

Wheel Section

3. Solar and galactic cosmic rays of energies > 3.3 Mev per nucleon, using counter telescopes with scintillators and Cerenkow detectors.

M. F. Kaplon, C. Deney, B. Dennis
University of Rochester

4. Solar X-ray flux (8-20A) using gas-filled ionization chambers, and comparison with optical and radio aspects of sun.

R. G. Teske
University of Michigan

5. Earth albedo (1000A-4 microns) using photomultiplier tubes to measure reflected solar radiation.

   C. B. Neel, R. Griffin
   Ames Research Center

6. Emissivity stability of low temperature coatings.

   C. B. Neel, J. Millard
   Ames Research Center

7. Celestial X-ray and gamma ray astronomy (15-600 Kev) and study of solar bursts in these frequencies, using an NaI scintillation counter.

   L. E. Peterson
   University of California, La Jolla

8. Gamma ray astronomy and search for non-solar gamma ray sources with energies above 100 Mev.

   W. L. Kraushaar
   University of Wisconsin

   G. W. Clark, G. Garmire
   Massachusetts Institute of Technology

OSO-F

Pointing Section

1. Solar X-ray (3-9A, 8-18A) using spectroheliograph with proportional counters.

   R. L. F. Boyd, A. Willmore
   University College, London

   K. A. Pounds
   University of Leicester

2. Solar monitoring with extreme ultraviolet spectroheliograph, 1216A, 584A, 304A and probably 335A and 284A.

   J. D. Purcell, R. Tousey, C. Detwiler
   Naval Research Laboratory

3. Solar X-ray and UV spectrum using spectrometers (1-400A) and X-ray ion chambers (1-8A and 10-20A).

W. M. Neupert, W. E. Behring, W. A. White
Goddard Space Flight Center

Wheel Section

4. Monitor solar x-radiation 8-16A, 2-8A, 0.5-3A, 0.1-1.6A with ion chamber photometers.

T. A. Chubb, R. W. Kreplin, H. Friedman
Naval Research Laboratory

5. Study low energy solar gamma rays (5-150 Kev) using scintillation detector.

K. Frost, H. Horstman, E. Rothe
Goddard Space Flight Center

6. Monitor self-reversal of the solar Lyman-alpha line using a photometer with an atomic hydrogen absorption cell.

J. Blamont
University of Paris

7. Measure intensity and polarization of the zodiacal light in visible and IR regions, with photomultipliers and polaroid filters.

E. P. Ney
University of Minnesota

8. Monitor solar far-ultraviolet radiation, 280-370A, 465-630A, 760-1030A, with concave grating and photomultiplier.

W. A. Rense, R. Parker
University of Colorado

OSO-G

Pointing Section

1. Normal incidence spectrometer-spectroheliometer (300 - 1300A) to scan the total spectral range at a point on the solar disk and to scan the sun at a fixed wavelength in the range.

L. Goldberg, E. M. Reeves, W. H. Parkinson
Harvard College Observatory

2. Bragg crystal spectrometer with three Geiger counters to measure solar X-rays (0.6 to 25A); a scintillation spectrometer to measure X-rays (0.6 to 6A); and three filtered Geiger counters functioning as X-ray burst detectors to monitor the radiation from the solar disk (1-8A, 8-16A, and 44-60A).

   R. W. Kreplin, J. F. Meekins, T. A. Chubb, H. Friedman
   Naval Research Laboratory

Wheel Section

1. Study the zodiacal light for brightness and polarization in many wavelengths.

   A. L. Rouy, B. Carroll, L. H. Aller
   Rutgers University

2. Monitor solar X-rays in the 16-40A region.

   H. V. Argo, J. A. Bergey, W. D. Evans, D. L. Henke,
   Los Alamos Scientific Laboratories

3. Monitor solar X-rays (20-200 Kev) and measure the albedo flux of photons.

   D. Brini, M. Galli, U. Ciriegi, F. Fuligni,
   E. Moretti, D. Cattani
   University of Bologna

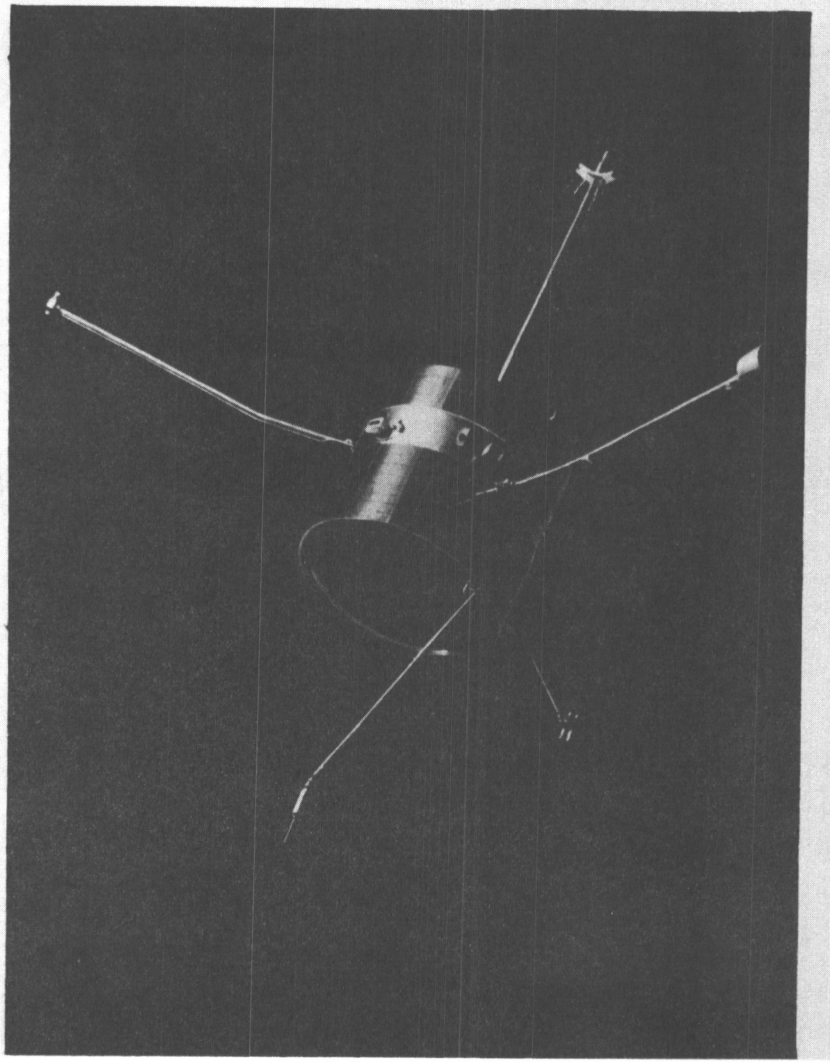
4. Study the HeI (584A) and HeII (304A) resonance radiation, and correlate with ground-based observations.

   R. L. F. Boyd, B. Woodgate
   University College, London

5. Determine high energy neutron flux (20 to 130 Mev).

   C. P. Leavitt
   University of New Mexico

PIONEER



GROSS WEIGHT	- 140 LBS
INSTRUMENT WEIGHT	- 34 LBS
INVESTIGATIONS	- 6
POWER	- 50 WATTS
STABILIZATION	- SPIN
DESIGN LIFE	- 6 MONTHS
LAUNCH VEHICLE	- THRUST AUGMENTED IMPROVED DELTA
TRAJECTORY	- INTERPLANETARY
STATUS	VI AND VII OPERATIONAL NEXT FLIGHT 1967

NASA SD63-1453
Rev. 11-17-66

PIONEER

NASA is launching a series of spacecraft, designated Pioneer, to investigate interplanetary phenomena on a continuing basis and at widely separated points in space. The spacecraft can operate in the region between 0.8 AU and 1.2 AU in the ecliptic plane, and they are as magnetically clean as the state of the art permits for measuring low-level magnetic fields.

Two spacecraft have been launched in the current series. Pioneer VI, launched December 16, 1965, has an orbit with a perihelion of 0.814 AU and an aphelion of 0.984 AU. It is operational and continues to be tracked as it leads Earth by more than 1 AU. Pioneer VII, launched August 17, 1966 with a payload which is the same as that on VI, lags Earth in an orbit with aphelion of 1.13 AU and perihelion of 1.0 AU.

Pioneers C, D, and E will have new payloads and will be launched in the 1967-1969 time period.

Pioneer C, D and E Payload

1. Magnetometer - a three-orthogonal component fluxgate magnetometer, each sensor having a dynamic range of ± 200 gamma and a sensitivity of 0.2 gamma, will monitor the interplanetary magnetic field and its fluctuations.

   C. P. Sonett, W. J. Kerwin, D. L. Colburn
   Ames Research Center

2. Plasma Probe - a quadrispherical electrostatic analyzer, employing eight separate current collectors, will provide angular distribution in the polar meridian plane. Energy coverage is from 200 ev to 16 kev in two sets of ranges for protons and from 3 ev to 1 kev for electrons.

   J. H. Wolfe, R. W. Silva
   Ames Research Center

3. Cosmic Ray Telescope - a time-multiplexed triple-purpose telescope will measure the intensity and energy spectrum of protons, alpha particles, and heavier nuclei in the range 1 Mev to greater than 1 Bev.

   W. R. Webber, G. Bingham
   University of Minnesota

4. Cosmic Ray Detector - count protons and alphas, using high and low counting rate detectors capable of resolving the anisotropy in the galactic and solar cosmic radiation.

   K. G. McCracken, W. C. Bartley, U. R. Rao
   Graduate Research Center of the Southwest

5. Radio Receivers - two receivers, one at 50 Mc/s and the other at 425 Mc/s for receiving signals from two transmitters (30 and 300 kw) emitting from the Stanford 150-foot steerable parabolic dish will measure average interplanetary electron density between the Earth and the probe, and its time variations.

V. R. Eshleman, O. K. Garriott, A.M. Peterson, B.B. Lusignan
Stanford University

R. L. Leadabrand
Stanford Research Institute

F. L. Scarf
TRW Systems

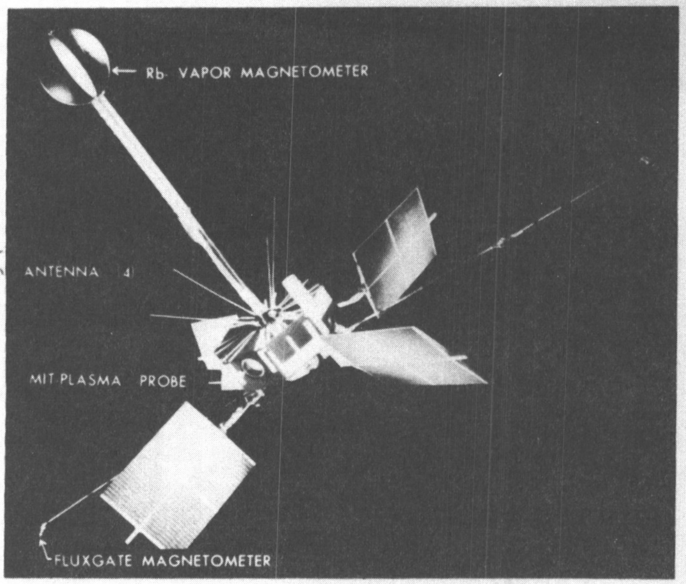
6. Cosmic Dust Detector - four sensors mechanically and electrically integrated will measure the particle time of flight, approximate radiant, impact impulse and cross section of impact crater to determine mass, density, and orbits of dust particles.

<u>Pioneer C & D</u> O. E. Berg, L. Secretan
Goddard Space Flight Center

W. M. Alexander
Temple University

<u>Pioneer E</u> O. E. Berg
Goddard Space Flight Center

INTERPLANETARY EXPLORER (IMP)



GROSS WEIGHT	135/181 LBS.
EXPERIMENTS	8 TO 11
POWER	16 WATTS
STABILIZATION	SPIN
DESIGN LIFE	1 YEAR
LAUNCH VEHICLE	DELTA
ORBIT	HIGHLY ELLIPTICAL EARTH ORBIT, OR ELLIPTICAL LUNAR ORBIT
STATUS	FIRST IMP 1963 FIFTH IMP 1967

NASA SP65-16316
Rev. 11-17-66

INTERPLANETARY EXPLORERS (IMP)

The primary objective of the Interplanetary Explorer Project is to study the radiation environment of cislunar space throughout a solar cycle. The Interplanetary Explorers belong to the general group of small satellites, and will be placed in highly elliptical Earth orbits or lunar orbits by means of the Delta launch vehicle.

Four of the seven missions which have been approved are already in Earth orbits: Explorer XVIII launched November 27, 1963; Explorer XXI launched October 3, 1964; Explorer XXVIII launched May 29, 1965; and Explorer XXXIII launched July 1, 1966.

The fourth and sixth Interplanetary Explorers (Explorer XXXIII and IMP E) were planned for measurements near the Moon while the spacecraft are in loose elliptical lunar orbits with altitudes ranging between 200 and 26,000 miles. Although Explorer XXXIII did not achieve the planned anchored lunar orbit, valuable data are being acquired. IMP E is scheduled for launch in 1967. Experiments on IMPs E, F and G are listed below.

IMP-E

1. Measure the vector magnetic field from 0 to 200 gammas, with closed loop, saturable core fluxgate magnetometers.

   C. P. Sonett, J. H. Wolfe, W. J. Kerwin, R. W. Silva,
   D. L. Colburn
   Ames Research Center

2. Measure the vector magnetic field from 0 to 64 gammas, with a triaxial fluxgate magnetometer.

   N. F. Ness
   Goddard Space Flight Center

3. Determine the energetic particle flux of protons (>0.5, 17 and 50 Mev), and electrons (>45 Mev), using an ion chamber and Geiger tubes.

   K. A. Anderson
   University of California, Berkeley

4. Detect low energy interplanetary electrons (>40 and >60 Kev), protons (0.5 to 8 Mev and 0.9 to 3.5 Mev), and alpha particles (2 to 20 Mev), using GM tubes and solid state detectors.

   J. A. Van Allen
   University of Iowa

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5. Measurement of the ionization, momentum, speed and direction of micrometeorites using thin film charge detectors, induction devices, and microphones.

J. L. Bohn and W. M. Alexander
Temple University

O. E. Berg
Goddard Space Flight Center

6. Determine the flux of positive and negative charged particles (100 ev to 10 Kev), using a retarding potential analyzer.

H. S. Bridge, A. J. Lazarus, E. F. Lyon
Massachusetts Institute of Technology

7. Make passive observations of unmodified telemetry signal

A. M. Peterson, V. R. Eshleman, O. K. Garriott,
R. L. Leadabrand, B. B. Lusignan
Stanford University

8. Study the lunar "geoid" through an analysis of orbital data.

W. M. Kaula
University of California, Los Angeles

IMP-F and IMP-G

The fifth and seventh Interplanetary Explorers (IMPs F and G) are scheduled for launch in 1968 and 1969 into elliptical Earth orbits with apogee of about 122,000 miles, perigee of about 125 miles and inclination of 66°. The investigations selected are as follows:

1. Determine integrated ionization from protons (>17 Mev), electrons (>1 Mev) and X-rays (>100 Kev), with a Neher-type ionization chamber. Measure the absolute flux of electrons (about 45 Kev and 120 Kev) using two thin-window Geiger tubes.

K. A. Anderson
University of California, Berkeley

2. Measure the vector magnetic field from 0 to 64 gammas, using a triaxial fluxgate magnetometer.

N. F. Ness
Goddard Space Flight Center

3. Study cosmic ray anisotropy, protons and alpha particles (10 to 100 Mev), and alpha particles (200 to 400 Mev), with a particle telescope.

K. G. McCracken, W. C. Bartley, U. R. Rao
Graduate Research Center of the Southwest

4. Determine composition of cosmic ray protons (0.5 to 85 Mev), alpha particles and higher Z nuclei (above 6 Mev per nucleon).

J. A. Simpson, C. Y. Fan
University of Chicago

5. Determine the quiet time galactic proton and alpha particle energy spectra (12-80 Mev per nucleon interval) and the modulation of the ratio of these two particles by solar activity; also study the intensity and modulation processes involving 1-20 Mev electrons; using a telescope with three scintillators, two in a dE/dx-E configuration and one as an anti-coincidence detector.

F. B. McDonald, G. H. Ludwig
Goddard Space Flight Center

6. Measure the particle flux with a low energy cosmic ray detector for protons (0.4 to 8 Mev), and alpha particles (2 to 8 Mev per nucleon).

F. B. McDonald, G. H. Ludwig
Goddard Space Flight Center

7. Study the proton and electron spectra (0.10 to 50 Kev) by means of a cylindrical electrostatic analyzer.

J. A. Van Allen, L. A. Frank, W. A. Whelpley
University of Iowa

8. Using a low energy particle telescope, detect and measure fluxes and energy spectra of electrons (0.3 to 3.0 Mev), and protons (0.5 to 18 Mev).

W. L. Brown, C. S. Roberts, G. L. Miller
Bell Telephone Laboratories

9. Study the azimuthal direction of arrival and intensity of protons (100 ev - 10 Kev) and electrons (5 - 100 Kev) using a spherical electrostatic analyzer.

F. B. Harrison, J. L. Vogl
TRW Systems

10. Detect and measure positive ions up to 10 Kev per unit charge, using a cylindrical electrostatic analyzer, for m/z = 1 and 2.

K. W. Ogilvie
Goddard Space Flight Center

T. D. Wilkerson
University of Maryland

11. Monitor energetic protons, using three solid state radiation detectors, in the following four energy ranges:

(a) $E_p > 60$ Mev, 3×10^3 protons/cm^{2}sec.
(b) $E_p > 30$ Mev, 2×10^4 protons/cm^{2}sec.
(c) $E_p > 10$ Mev, 2×10^5 protons/cm^{2}sec.
(d) $1 < E_p < 10$ Mev, 3.3×10^4 protons/cm^{2}sec.

Alpha particles of roughly four times the proton energies will fall into the same channels.

C. Bostrom
Applied Physics Laboratory

D. E. Hagge, F. B. McDonald, D. Williams
Goddard Space Flight Center

AIR DENSITY/INJUN-C

The Air Density/Injun-C payload consists of two independent spacecraft to be launched simultaneously by a Scout into a nearly polar, eccentric orbit with a perigee of about 300 miles and an apogee of 2700 miles. The Air Density spacecraft is a 12-foot inflatable sphere of the same basic design as Explorers IX, XIX, and XXIV, and will continue the measurements of the density of the upper atmosphere through changes in drag as shown by orbital changes. The Injun spacecraft is designed to measure the down-flux of corpuscular radiation into the Earth's atmosphere and to determine the effects of the radiation upon the upper atmosphere. Measurements also will be made of very low frequency radio emissions in the ionosphere. The flux data will be correlated with atmospheric density data. Launch is scheduled for late 1967.

The investigations and investigators are:

Air Density Explorer

1. Determine systematic changes in the air density as a function of altitude, latitude, and time of day.

    W. J. O'Sullivan, C. Coffee, G. Keating
    Langley Research Center

2. Determine non-systematic changes in atmospheric density caused by short-term differences in solar activity.

    L. Jacchia
    Smithsonian Astrophysical Observatory

Injun

1. Study precipitated and trapped electrons and protons (75 ev - 75 kev), and their correlation with air density, particle temperature, and VLF emissions, by using a curved plate electrostatic analyzer, a retarding potential analyzer, and a Geiger Mueller tube.

    J. A. Van Allen, L. A. Frank
    University of Iowa

2. Measure frequency, amplitude, and polarization of natural and artificial VLF emissions, using two balanced dipoles and corresponding receivers (30 cps - 16 kc/s).

    J. A. Van Allen, D. A. Gurnett, S. D. Shawhan
    University of Iowa

3. Measure energy spectra, angular distribution and time dependence of absolute intensities of protons (200 kev - 21 Mev), alpha particles (1.5 - 10 Mev), and electrons (200 kev - 1.2 Mev) with three solid state detectors.

J. A. Van Allen, T. P. Armstrong, S. M. Krimigis
University of Iowa

4. Study spatial and temporal variations in the concentration and energy distribution of low energy charged particles (0-2 kev) with two four-grid spherical retarding potential analyzers.

R. C. Sagalyn, M. Smiddy
Air Force Cambridge Research Laboratories

OWL EXPLORERS

The OWL Explorer is a satellite designed to study near-Earth atmospheric phenomena, particularly the characteristics of aurora and of the air-glow, as they correlate with the trapped radiation belts and precipitated radiation. Diurnal and conjugate effects are to be investigated.

Two identically designed and equipped satellites will be launched by Scout vehicles one month apart in late 1967 or early 1968. Each will be placed in a circular orbit at altitudes of approximately 500 miles (800 km) and 450 miles (700 km) respectively with an inclination of 80°. The two orbits will have coincident lines of nodes.

Rice University is responsible for the design, development, fabrication, integration, and testing of the satellite, including pre-launch checkout and preparation. Facilities of NASA may be used for any required testing beyond the capability of Rice University. Each OWL is planned to weigh 140 pounds, and will have passive magnetic orientation. The two OWL's will differ in the directions of their magnetic axes. While one OWL views the northern hemisphere, the other will view the southern.

The investigations to be flown on the two OWL's are the following:

1. Make coordinated measurements of the light of aurorae and of the energetic particles causing them.

   B. J. O'Brien

2. Measure the intensity of the auroral light at the wavelengths 5577A (oxygen), 3914A (nitrogen), and 4861A (hydrogen).

   B. J. O'Brien, H. Goldwire

3. Measure the flux of electrons and protons bombarding the atmosphere and becoming trapped, and determine their energy spectra and pitch angles.

   B. J. O'Brien, J. W. Freeman, Jr., D.C. Laughlin,
   R. LaQuey, H. Goldwire, T. Winiecki

4. Measure the temporal and spatial variations in the pitch-angle distribution of electrons with $E > 40$ kev.

   B. J. O'Brien, L. Westerlund, D. Criswell

5. Measure the number flux and total energy of fast neutral hydrogen atoms.

   B. J. O'Brien, R. Allum, A. J. Dessler

6. Measure the local-time and conjugate-area variations of aurorae, of the boundary of trapping precipitated fluxes, and of solar proton fluxes.

   B. J. O'Brien

7. Measure the intensity of light at 5577A, 3914A, and 4861A.

   B. J. O'Brien

8. Measure the spatial distribution of the light emitted in aurorae.

   B. J. O'Brien, M. Trichel

9. Monitor the flux of solar cosmic rays and their energy deposition in the atmosphere in both hemispheres.

   B. J. O'Brien, R. Haymes, L. Westerlund
   H. Goldwire, C. Laughlin

10. Monitor the flux of cosmic rays and of the albedo.

   B. J. O'Brien, L. Westerlund, C. Laughlin

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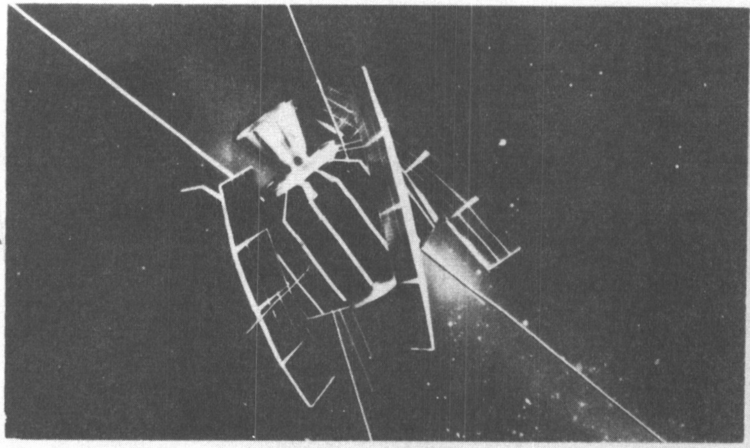
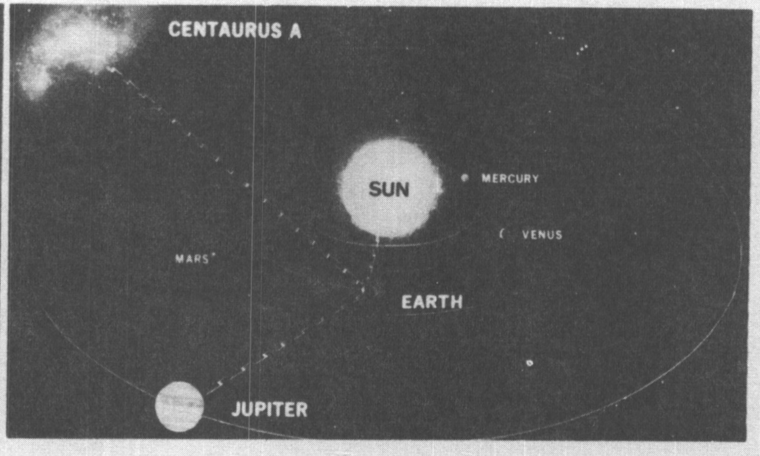
RADIO ASTRONOMY EXPLORER





GROSS S/C WEIGHT 402 LBS
ANTENNA WEIGHT 76 LBS
EXPERIMENTS - 3
POWER - 19 WATTS

STABILIZATION - GRAVITY
LAUNCH VEHICLE -
THRUST AUGMENTED
IMPROVED DELTA

ORBIT
3700 MILES
CIRCULAR
INCLINATION - 58° - RETROGRADE

STATUS - LAUNCH IN 1967

NASA SG65-779
REV. 11-21-66

RADIO ASTRONOMY EXPLORERS (RAE)

The Radio Astronomy Explorer is designed to measure the frequency, intensity, and direction of radio signals from celestial sources in the frequency range from 0.25 MHz to 9.2 MHz. The experiments will investigate galactic phenomena, and will observe sporadic low frequency solar radio bursts, sporadic Jovian bursts, sporadic radio emissions from Earth, discrete cosmic sources, and plasma oscillations. The mission will accomplish the first mapping of our galaxy at frequencies below ionospheric cutoff.

The first RAE will be launched into a circular orbit of 3700 miles diameter with an inclination of 58° retrograde, by means of a Delta launch vehicle and apogee kick motor. Two missions have been approved, and the first flight is scheduled for 1967. The experiments which have been selected are as follows:

1. Measure the impedance behavior of the antenna and of the local plasma parameters by use of a capacitance probe, an impedance probe, and an electron trap below the atmospheric cut-off (0.25 MHz - 8 MHz).

   R. G. Stone, J. Donley, R. Somerlock, J. Guthrie, and J. Kane - Goddard Space Flight Center

2. Measure long wavelength solar and planetary emissions by means of a long antenna and a "fast burst" radiometer. (0.25 MHz - 5.5 MHz)

   R. G. Stone, J. Alexander, and H. Malitson
   Goddard Space Flight Center

3. Map the intensity distribution of cosmic radio emissions at frequencies below the ionospheric cut-off (0.45 MHz - 9.2 MHz) by means of two long directive antennas and a radiometric system.

   R. G. Stone, R. Weber, and L. Brown
   Goddard Space Flight Center

NRL/NASA SOLAR EXPLORER - B

The NRL/NASA Solar Explorer - B is the second in a series of NRL/NASA cooperative spacecraft projects to monitor the solar X-ray emission. The overall objectives are to:

1. Continue to monitor the Sun's energetic X-ray and Lyman-Alpha emission over a complete solar cycle with standardized X-ray photometers;

2. Measure the time history of X-ray emission intensity and spectral quality of solar flare emissions in the wavelength bands 0.5 to 60 and 1080 to 1350A; and

3. Correlate these measurements with those of optical and radio ground-based observations.

NRL is responsible for the design, fabrication, and tests of the spacecraft. NASA will provide the launch vehicle and will conduct the launch operations. Tracking and data acquisition will be accomplished jointly by NASA (STADAN) and NRL.

The NRL/NASA Solar Explorer-B will be launched from Wallops Island into a circular orbit of 450 ± 50 n. miles with an inclination of 60°-65° by a Scout vehicle in 1967.

The principal investigator is Robert W. Kreplin, NRL, and the co-investigators are T.A. Chubb and H. Friedman.

ESRO

There are two ESRO (European Space Research Organization) projects planned. These are cooperative international projects whereby ESRO will provide the spacecraft and experiments and NASA will provide the launch vehicle and launch support. Launches are scheduled for 1967.

ESRO I

ESRO I is to be launched by a Scout into a polar eccentric orbit with perigee of about 175 miles, apogee about 950 miles, and inclination of 90°. The scientific objective is to conduct an integrated study of high latitude energetic particles and their effects on the polar ionosphere. The payload will include a beacon experiment for measurements of the total electron content between the satellite and ground observers.

The investigations and investigators are:

1. Corpuscular radiation

   O. E. Peterson
   Technical University, Denmark

   W. Riedler
   Kiruna Geophysics Observatory, Sweden

   R. Dalziel
   Radio Research Station, England

2. Electron temperature and density

   A. P. Willmore
   University College, London, England

3. Ion Composition

   A. P. Willmore
   University College, London, England

4. Auroral Photometry

   A. Omholt
   University of Oslo

   D. R. Bates
   Queen's University, Belfast

ESRO II

ESRO II is to be launched by a Scout into a polar eccentric orbit with perigee of about 200 miles, apogee of about 750 miles, and inclination of 98°.

The scientific areas of ESRO II are solar radiation and cosmic rays.

The investigations and investigators are:

1. Solar X-Rays (1 to 70A wavelength)

    E. A. Stewardson and K. A. Pounds
    Leicester University

    R. L. F. Boyd and J. L. Culham
    University College, London

    C. de Jager and W. de Graaff
    Sterrenwacht, Utrecht, Holland

2. Trapped radiation

    H. Elliot and J. J. Quenby
    Imperial College, London

3. Solar and inner Van Allen Belt protons (1-100 Mev)

    H. Elliot and J. J. Quenby
    Imperial College, London

4. Cosmic ray protons and alpha particles (85-350 Mev)

    H. Elliot and J. J. Quenby
    Imperial College, London

5. High energy electrons (500 Mev and 5 Gev)

    P. L. Marsden
    University of Leeds

6. Solar and cosmic ray protons (35-1000 Mev)

    J. Labeyrie and L. Koch
    Saclay, France

ISIS

ISIS (International Satellites for Ionospheric Studies) is a NASA/Canadian Defence Research Board undertaking to study the ionosphere from sunspot minimum through sunspot maximum by means of a series of ionospheric research satellites. The program was begun with Alouette I launched September 29, 1962, and continued with Alouette II launched November 29, 1965.

ISIS-A

ISIS-A is to be launched in 1967 by an improved Delta into a low altitude, nearly polar orbit with a perigee of approximately 500 km (300 miles), an apogee of 3,500 km (2,200 miles), and an inclination of 80°.

The investigations and investigators are:

1. Determine the electron density, using a sweep frequency sounder (0.1 to 16 Mc/s).

    J. H. Chapman
    DRTE, Canada

2. Study small irregularities in the ionosphere, using a fixed frequency sounder.

    J. H. Chapman
    DRTE, Canada

    W. Calvert
    T. E. Van Zandt
    ITSA/ESSA

    G. L. Nelms
    L. E. Petrie
    DRTE, Canada

3. Obtain scintillations and integrated electron content, with radio beacons operating at 136 and 137 MHz.

    J. H. Chapman
    DRTE, Canada

    P. A. Forsyth
    G. F. Lyon
    E. H. Tull
    University of Western Ontario

4. Monitor the background cosmic radio noise, using a sweep frequency receiver.

   T. R. Hartz
   DRTE, Canada

5. Monitor ELF/VLF emissions from upper atmosphere, using receiver sensitive to 0.05 to 30 Kc/s.

   J. S. Belrose
   DRTE, Canada

6. Study positive and negative particles in three overlapping ranges, 10 ev to 10 Kev, using an electrostatic detector.

   W. J. Heikkila
   Graduate Research Center of the Southwest

7. Study the electron temperature and density with two cylindrical Langmuir probes.

   L. H. Brace
   J. A. Findlay
   Goddard Space Flight Center

8. Study energetic charged particles in lower part of outer radiation belt, using geiger counters for electrons (40-780 Kev), and silicon junction detectors for protons (100 Kev to 63 Mev).

   I. B. McDiarmid
   D. C. Rose
   J. R. Burrows
   E. E. Budzinski
   National Research Council of Canada

9. Study positive ion density and temperature, using a spherical ion retarding potential analyzer in altitude range from 1,000 to 3,500 Km.

   R. C. Sagalyn
   M. Smiddy
   Air Force Cambridge Research Laboratories

10. Make positive ion measurements using an ion mass spectrometer with mass range of 1 to 20 AMU and density range from 5 to 5×10^5 ions/cm^3.

   R. S. Narcisi
   A. D. Bailey
   Air Force Cambridge Research Laboratories

Investigations and Investigators

1. **Conduct, using a Swept Frequency Topside Sounder (Swept and Fixed Frequency Mode), a systematic exploration of the electron density distribution on the topside of the ionosphere throughout a solar cycle and through a large range of latitudes, longitudes, seasons and times of day.**

   E. S. Warren
   Defence Research Telecommunications Establishment (DRTE), Canada

   G. E. K. Lockwood DRTE
   L. E. Petrie DRTE
   G. L. Nelms DRTE

2. **Measure background radio noise levels over the range 0.1 to 20 MHz covered by the sounder receiver in order to identify signals of man-made, ionospheric, solar and galactic origins.**

   T. R. Hartz DRTE

3. **Study naturally-occurring VLF emissions; determine ion composition by observation of ion cyclotron whistlers, and conduct experiments to stimulate ion resonances by excitation.**

   R. E. Barrington DRTE

4. **A radio beacon will provide facilities for investigators to observe scintillations from irregularities, and to evaluate electron content.**

   P. A. Forsyth
   University of Western Ontario, Canada

   G. F. Lynn, Univ. of Western Ontario, Canada
   E. H. Tull, Univ. of Western Ontario, Canada

5. **Use a soft-particle spectrometer to relate flux, spectrum and pitch angles of positive and negative particles (10 ev-10 Kev) to electron density distribution, visible aurorae, and VLF emissions measured on the same satellite, particularly at high latitudes.**

   W. J. Heikkila
   Graduate Research Center of the Southwest

6. **High latitude investigation of energetic charged particles in lower portion of radiation belt; study of precipitation, and search for relation to VLF phenomena.**

    I. B. McDiarmid
    National Research Council (NRC) of Canada

    J. R. Burrows
    National Research Council (NRC) of Canada

7. **Measure positive ion composition at satellite altitudes with cross-check with the H^+ and He^+ abundances data from the VLF experiment, to provide an upper boundary condition for the interpretation of the measurement-in-depth given by the sounder.**

    J. H. Hoffman
    Graduate Research Center of the Southwest

8. **Use a cylindrical electrostatic probe to determine global variation of electron temperature; correlative measurements of electron concentration and ion mass, for comparison with other experiments; and electronic fine structure in polar regions.**

    L. H. Brace,
    Goddard Space Flight Center

    J. A. Findlay
    Goddard Space Flight Center

9. **Using a retarding potential analyzer to measure ion and electron current to study heat transfer processes important in dynamic of ionosphere.**

    J. L. Donley
    Goddard Space Flight Center

    E. J. R. Maier
    Goddard Space Flight Center

10. **Use a scanning photometer to make auroral studies relating emissions (3914Å and 5577Å) to ionospheric parameters and precipitated particles measured on same vehicle.**

    C. D. Anger
    University of Calgary, Alberta, Canada

11. **Measure 6300Å atomic oxygen emission in the nightglow, twilight glow, dayglow, aurora and midlatitude red arcs to relate the emission to F-region parameters.**

C. G. Shepherd
University of Saskatchewan, Canada

ISIS-C

ISIS-C has been approved, but experiments have not been selected. A magnetospheric orbit has been recommended.

SAN MARCO

The San Marco program is a NASA/Italian cooperative effort. The primary objective of the program is to obtain a direct, continuous measurement of atmospheric density in the equatorial region in the altitude range between 120 and 240 miles, as determined by the analysis of the atmospheric drag on the satellite. A secondary objective is to determine the electron content between the satellite and Earth. The spacecraft consists of two spherical shells, one within the other. Motion of one relative to the other will be measured with displacement transducers arranged on three orthogonal axes in order to deduce the atmospheric drag on the outer sphere. The experiments and experimenters are as follows:

1. Measure atmospheric parameters by means of strain gage drag balance between two concentric spheres.

   L. Broglio
   University of Rome, Italy

2. Obtain integrated electron content with radio beacon at 20 Mc/s.

   N. Carrara
   Microwave Center, Florence, Italy

The SM-I was launched on December 15, 1964, from Wallops Island, but starting in 1967, primary mission launchings will be from a platform in the Indian Ocean.

UK-E

The UK-E is the third in the series of joint NASA/UK undertakings. Ariel I and Ariel II were both successful. UK-E is to be launched by a Scout vehicle into a nearly circular orbit of approximately 370 miles altitude, and inclination of 57°. The following investigations have been selected to meet the scientific objectives which are to continue the examination of the ionosphere and to continue radio experimentation. It is scheduled for launch in 1967.

1. Continuous measurement of ionization density and temperature.

   J. Sayers
   University of Birmingham

2. Measurement of the vertical distribution of molecular oxygen.

   R. Frith
   Meteorological Office, England

3. Mapping large scale noise sources in the galaxy.

   F. G. Smith
   University of Cambridge

4. Radio signals below 20 Kc/s.

   T. R. Kaiser
   University of Sheffield

5. Terrestrial radio noise

   J. A. Ratcliffe
   Radio Research Station

OSSA SCIENTIFIC BALLOON PROGRAM

The Office of Space Science and Applications (OSSA) supports a program of balloon flights to carry scientific instruments into space to the altitudes available to balloons.

Balloon launch sites are available to NASA investigators at:

Fort Churchill, Canada, for launches from June to September

Flin Flon, Canada, for launches from June to September

Palestine, Texas

Page, Arizona

Equipment needed for determining balloon altitude and orientation will be provided. Telemetry equipment can be provided if desired. An FM/FM telemetry system is most commonly used.

Typical experiments supported in 1966 have investigated cosmic rays, auroral activity, the solar corona, and interplanetary dust.

CONVAIR 990 RESEARCH AIRCRAFT

The Convair 990 research aircraft is a four-engine, high altitude, long-range, high-speed jet transport airplane with a maximum cruising speed of 1000 kilometers per hour. It is, in effect, a manned laboratory with the capability of carrying bulky and heavy observational instruments and equipment, together with the experimenters. The aircraft is based at the NASA Ames Research Center, Moffett Field, California. The airplane may be flown to an altitude of about 45,000 feet, and operated from an advanced base nearly anywhere in the world. The aircraft's experimental program includes space science and aeronautical research projects.

Major airborne space science experiments successfully completed include:

1. Solar Eclipse Expedition, May 1965, over the South Pacific (photographic, spectrographic, and polarization studies of the solar corona in the visible and infrared)

2. October 1965 Airborne Expedition for photographic and spectroscopic measurements of the Comet Ikeya-Seki (1965f) during perihelion passage

3. Observations of the stable libration centers for study of Kordalewski clouds

4. Meteorology and Surface Mapping Expedition from various U.S. and South American bases during April and May 1966

5. Solar Eclipse Expedition, November 1966, South America (approximately 10 space science experiments to study the solar corona and ionospheric motions)

Some of the space science experiments planned for 1967 include:

1. Second Meteorological Expedition

2. Infrared astronomy of the Sun

3. Auroral and Polar Cap Expedition from Fort Churchill, Canada

4. Galactic infrared astronomy

5. Circadian rhythm project

X-15 Aircraft

Technical considerations have limited the availability of the X-15A-2 research aircraft to a ceiling of about 100,000 feet for scientific investigations and at this altitude it is available for only relatively short stays on the order of 1 to 2 minutes.

Since the Convair 990A research aircraft is serviceable with heavy equipment to altitudes up to about 45,000 feet, for durations of hours if necessary, there appears to be little benefit in scheduling scientific investigations on the X-15.

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SOUNDING ROCKETS

The Physics and Astronomy Program Office of NASA conducts a Sounding Rocket Program in support of scientific space research in the following areas:

Energetic Particles and Fields
Planetary Atmospheres
Micrometeorite and Cometary Dust
Galactic and Radio Astronomy
Ionospheric and Radio Physics
Solar Physics

Approximately 100 rocket flights per year are conducted from launch sites at: Wallops Island (WI), Virginia; Fort Churchill (FC), Canada; White Sands (WS), New Mexico; Natal, Brazil; Point Barrow (PB), Alaska; Kiruna, Norway; and Thumba, India. These flights are conducted utilizing operational rockets developed by NASA; namely, Boosted Arcas, Nike Apache, Nike Cajun, Nike Tomahawk, Aerobee 150, and Javelin (Argo D-4) as well as the Aerobee 350 and Astrobee 1500 which are currently in the final stages of development. The payloads flown on these rockets are scientific experiments developed by scientists from universities, non-profit scientific organizations, NASA Field Centers, other government agencies and commercial scientific companies in the United States and several foreign countries.

The Sounding Rocket Program provides scientists with a relatively simple, flexible, inexpensive, and short-term method for conducting investigations over a wide range of altitudes which add to our knowledge of space; and efficient means of training graduate students and young scientists; and an opportunity to develop and test scientific instruments for use on satellites and spacecraft.

A list of scientists that have experiments scheduled for launch on sounding rockets during the coming year **follows.**

INVESTIGATOR	INSTITUTION	EXPERIMENT	LAUNCH SITE
M. Harwit	Cornell University	Study stellar spectra in the infrared	WS
T. L. Aggson	Goddard	Instrumentation test flight	WI
J. A. Lockwood	University of New Hampshire	Latitudinal survey of cosmic ray neutrons, charged particles and X-ray flux	WI, FC, & Brazil
O. E. Berg	Goddard	Study electron and micrometeorite density and airglow	WS
E. J. Maier	Goddard	Study electron and ion composition, temperature, and density	WI
E. Whipple	ESSA	Determine local electron density and magnetic field in the ionosphere	WS
R. Giacconi	AS&E	Determine location and intensity of celestial X-ray sources	WS
D. C. Morton	Princeton	Study stellar spectra in the ultraviolet, search for interstellar molecular hydrogen	WS

INVESTIGATOR	INSTITUTION	EXPERIMENT	LAUNCH SITE
N. H. Farlow	Ames	Collect micrometeorites	WS
A. O. C. Nier	University of Minn.	Determine neutral composition profiles of the atmosphere	WS
J. R. Waters	AS&E	Flight test directional neutron detector developed for OGO	WI
B. J. O'Brien	Rice University	Study origins of particles that cause aurora	FC
R. Tousey M. J. Koomen	NRL	Measure solar flux at Lyman-alpha	WS
J. H. Underwood	Goddard	Study solar X-rays during solar eclipse	WS
L. G. Smith J. F. Beddinger	GCA	Study of luminescent clouds and the ionosphere during solar eclipse	Brazil
S. A. Bowhill	University of Illinois	Study electron density and neutral atmosphere in the lower ionosphere	Brazil
R. T. Bettinger	University of Maryland	Investigate electron energy distribution in the ionosphere	WI

INVESTIGATOR	INSTITUTION	EXPERIMENT	LAUNCH SITE
T. Stecher	Goddard	Measure ultraviolet radiation from early type stars	WS
C. L. Hemenway	Dudley Observatory	Micrometeorite particles and dust collection and analysis	WS
P. J. Kellogg	University of Minn.	Study electric and magnetic field variations in the magnetosphere	WI
E. T. Byram	NRL	Study stellar spectra in Orion region of the Milky Way	WS
R. G. Stone	Goddard	Measure cosmic radio noise background at low frequencies	WI
E. J. Schaefer	University of Michigan	Analysis of ambient composition of the atmosphere	FC
J. A. Kane	Goddard	Correlation of D-region electron density and noctilucent clouds	PB Norway
F. A. Volpe	Goddard	Test flight of Fine Attitude Control System (FACS)	WS
H. C. McAllister	University of Hawaii	Study atmospheric absorption and solar spectroscopy	WS

INVESTIGATOR	INSTITUTION	EXPERIMENT	LAUNCH SITE
R. Novick	Columbia Radiation Laboratory	Search celestial sphere for weak X-ray sources	WS
L. W. Acton	Lockheed	Measure intensity of solar X-rays	WS
R. Huguenin	Harvard University	Study cosmic noise background with instruments designed for Pilgrim	WI
W. N. Ness	Goddard	Study electron beam created to simulate aurora	WI
J. R. Herman	Goddard	Study composition, electron density and collision frequency in the ionosphere	WI
D. S. Evans	Goddard	Study energy and density of electrons in the aurora	FC
W. S. Muney	Goddard	Obtain solar spectral data to calibrate OSO spectrometer	WS
W. G. Fastie	Johns Hopkins University	Study auroral spectra in the far ultraviolet	FC
T. Violette	Western State College of Colorado	Study solar spectral emission near Lyman-alpha Beta line	WS

INVESTIGATOR	INSTITUTION	EXPERIMENT	LAUNCH SITE
E. A. Martell	NCAR	Collect air samples to determine atmospheric structure	WS
L. Goldberg	Harvard University	Obtain center-to-limb variation across the solar disc	WS
D. A. Gurnett	University of Iowa	Study VLF noise phenomena of ions in plasma around rocket	WI, & FC
W. J. Heikkila	GRCSW	Study auroral zone disturbances and polar cap absorption events	FC
J. P. Heppner	Goddard	Study auroral electrojet currents	FC
K. B. Mather	University of Alaska	Study electrojet currents and their relation to the aurora	FC
D. S. Evans	Goddard	Study stellar spectra in the ultraviolet	WS
E. Boldt	Goddard	Measure spectrum of celestial X-ray sources	WS
P. C. Fisher	Lockheed	Study low-energy X-ray background	WS
H. Bradt	MIT	Determine location and energy spectra of X-ray sources near galactic center	WS

INVESTIGATOR	INSTITUTION	EXPERIMENT	LAUNCH SITE
W. H. Hansen	Ames	Test flight of "Solar Pointing Aerobee Rocket Control System (SPARCS)"	WS
J. Pressman	GCA	Study airglow and chemical release experiment	FC
F. Haddock	University of Michigan	Study cosmic background spectrum	FC & WI
R. C. Haymes	Rice University	Study ionospheric current system	WI
C. S. Bowyer	Catholic University	Search for celestial X-ray sources	Brazil
A. J. Kruejer	Naval Ordnance Test Station	Measure solar ultraviolet irradiance and compare with OGO measurements	WS
J. R. Winckler	University of Minn.	Study trapped radiation belts	WI
E. V. Chitnis **U. R. Rao**	**INCOSPAR** **PRL, Ahmedabad**	**X-ray astronomy studies**	**Thumba**
T. S. G. Sastry **Satya Prakash**	**INCOSPAR** **PRL, Ahmedabad**	**Magnetic field characteristics study with magnetometer and Langmuir probe**	**Thumba**
P. D. Bhavsar	**PRL, Ahmedabad**	**Vapor cloud studies using Langmuir probe**	**Thumba**
Y. V. Somayajulu	**NPL, New Delhi**	**Studies of the ionosphere with riometers**	**Thumba**

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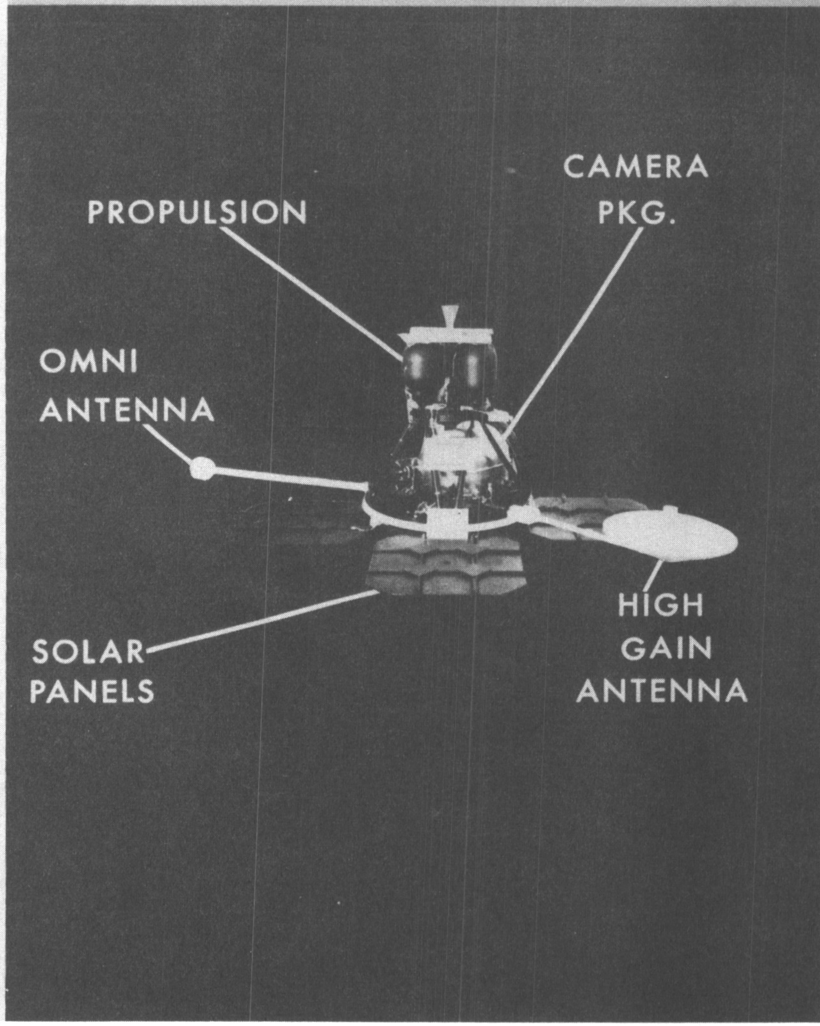
LUNAR AND PLANETARY

LUNAR ORBITER



GROSS WEIGHT	845 LBS
INSTRUMENT WEIGHT	150 LBS
INVESTIGATIONS	TELEMETERED FILM PHOTOGRAPHY SELENODESY ENVIRONMENTAL MEASUREMENTS
POWER	235 WATTS (MAX)
STABILIZATION	3 AXIS
DESIGN LIFE	1 YEAR [1 MONTH PHOTOG.]
LAUNCH VEHICLE	ATLAS-AGENA
TRAJECTORY	ECCENTRIC LUNAR ORBIT
STATUS	FIRST FLIGHT 1966 FUTURE LAUNCHES AT 3 MONTH INTERVALS

NASA SL64-201
Rev. 11-17-66

LUNAR ORBITER

The Lunar Orbiter Program is concerned with the placement of a series of five unmanned instrumented spacecraft into close-in elliptical orbits about the Moon to support investigations of the near-lunar environment and extended area photography of the lunar surface. The five Lunar Orbiter spacecraft missions are to be conducted during 1966 and 1967, with launches scheduled at three month intervals.

The primary objective for the Lunar Orbiter missions is the acquisition of detailed topographic and geologic information about the lunar surface through photography for use in selecting suitable landing sites for unmanned Surveyor and manned Apollo spacecraft. Secondary mission objectives are to provide precise trajectory information for use in improving the definition of the lunar gravitational field and to provide information on the micrometeoroid flux and radiation level in the lunar environment, primarily for spacecraft performance analysis.

The first Lunar Orbiter spacecraft was successfully launched on August 10, 1966. It returned photographs of nine primary potential Apollo landing sites, seven other potential Apollo landing sites, the east limb of the Moon, and the far side of the Moon. It also returned the first photographs of the Earth taken from the immediate vicinity of the Moon.

Thirteen other areas on the lunar surface within the Apollo zone of interest (45° east longitude to 45° west longitude, and 5° north latitude to 5° south latitude) have been selected by NASA as targets for photography during the second Lunar Orbiter mission. These areas are located in a narrow belt between the equator and 5° north of the equator. The locations of the centers of these areas are as follows:

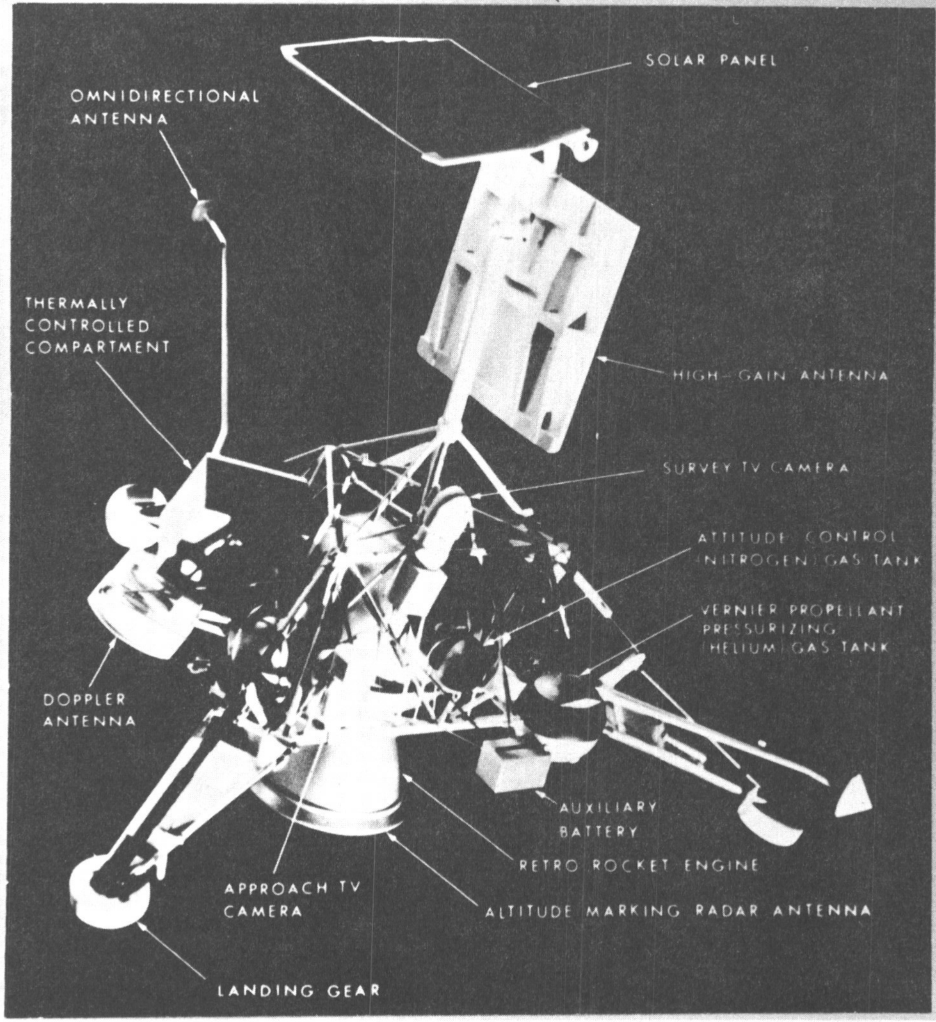
Area Number	Longitude	Latitude
B-1	36°55'E	4°10'N
B-2	34°00'E	2°45'N
B-3	21°20'E	4°20'N
B-4	15°45'E	4°45'N
B-5	24°48'E	2°36'N
B-6	24°10'E	0°45'N
B-7	2°00'W	2°10'N
B-8	1°00'W	0°05'N
B-9	13°00'W	1°00'N
B-10	27°10'W	3°28'N
B-11	19°55'W	0°05'S
B-12	34°40'W	2°25'N
B-13	42°20'W	1°30'N

As the spacecraft overflies each of the thirteen areas, a sequence of eight high- and medium-resolution pictures will be taken to provide contiguous one-meter-resolution coverage of an area 16 by 32 km, and 87 per cent 8-meter-resolution forward overlapping coverage of an area 36 by 60 km for stereo viewing.

The acquisition and transmission to Earth of all the pictures taken on one flight will take about 30 days. The information content in the pictures will be screened and assessed at the Langley Research Center by representatives from the Lunar Orbiter Project Office, the U. S. Geological Survey, the Manned Spacecraft Center, the Jet Propulsion Laboratory, the Air Force Aeronautical Chart and Information Center, and the Army Map Service.

Upon completion of the photographic phase of the mission, range and range-rate radio tracking data will be obtained continuously for 30 days and then intermittently for a period of ten months in order to satisfy the requirements of the selenodesy experiment being carried out jointly by Mr. William Michael, Jr., Principal Investigator, Langley Research Center (LRC); and the co-investigators, Mr. Robert Tolson (LRC), Mr. Jack Lorell (JPL), and Mr. Warren Martin (JPL).

SURVEYOR



GROSS WEIGHT	- 2200-2230 LBS
INSTRUMENT WEIGHT	- 28-45 LBS
EXPERIMENTS	- 2-3 PER SPACECRAFT
STABILIZATION	- ACTIVE 3 AXIS
PROPULSION	
RETROROCKET	- SOLID
VERNIER ROCKETS	- LIQUID
DESIGN LIFE	- 1 LUNAR DAY
LAUNCH VEHICLE	- ATLAS-CENTAUR
TRAJECTORY	- DIRECT ASCENT OR PARKING ORBIT
STATUS	- FIRST FLIGHT 1966

NASA SD63-1456
REV. 11-21-66

SURVEYOR

The Surveyor Project is the NASA lunar exploration project concerned with the soft landing of unmanned instrumented spacecraft on the Moon. Seven spacecraft of the engineering test configuration have been approved for flight. The first two of these carried a single survey television camera and touchdown strain-gage instrumentation. Spacecraft three and four will carry, in addition, a simplified surface sampler instrument. On spacecraft five, six, and seven, the surface sampler will be replaced by an alpha-backscatter experiment. Later Surveyors may carry other experiments.

Following is the currently approved list of Surveyor experiments and experimenters:

1. Television - two survey cameras to obtain stereo ranging and to make visual observations of lunar surface topographic and terrain features.

    E. M. Shoemaker - U.S. Geological Survey
    G. P. Kuiper - University of Arizona
    E. Whitaker - University of Arizona
    J. J. Rennilson - Jet Propulsion Laboratory
    E. C. Morris - U.S. Geological Survey
    R. Altenhofer - U.S. Geological Survey

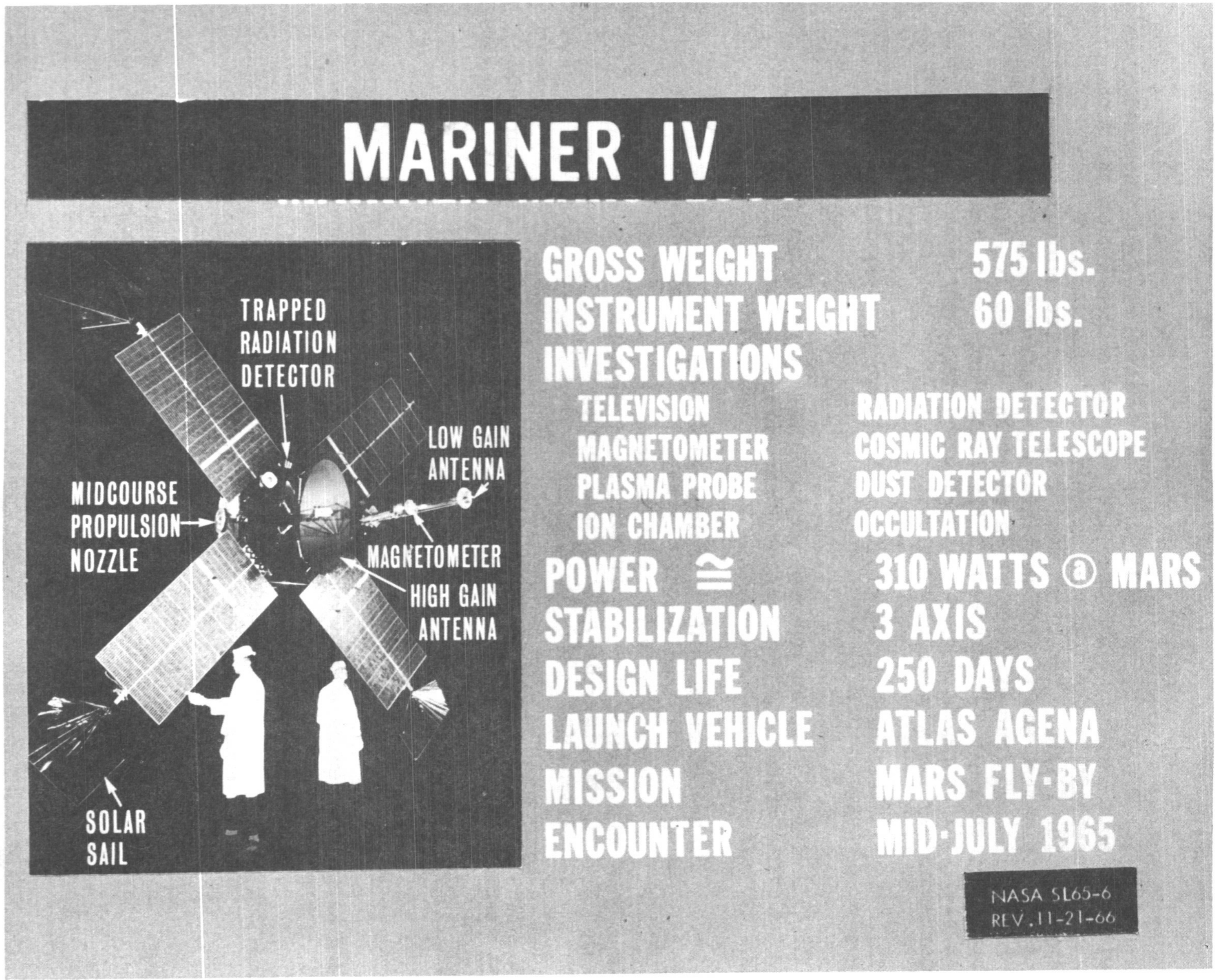
2. Surface Sampler/Soil Mechanics - to determine surface structure and mechanical properties of lunar surface material.

    R. F. Scott - California Institute of Technology
    R. M. Haythornwaite - University of Michigan
    R. A. Liston - U.S. Army Ordnance Land Locomotion Laboratory

3. Alpha Scattering - to perform elemental analysis of lunar surface material.

    A. Turkevich - University of Chicago
    J. Patterson - Argonne National Laboratory
    E. Franzgrote - Jet Propulsion Laboratory

The Surveyor Project will assist the Apollo Program by providing topographic and lunar surface bearing strength information needed to certify suitable landing sites.


MARINER IV
TRAPPED RADIATION DETECTOR
LOW GAIN ANTENNA
MIDCOURSE PROPULSION NOZZLE
MAGNETOMETER
HIGH GAIN ANTENNA
SOLAR SAIL
GROSS WEIGHT 575 lbs.
INSTRUMENT WEIGHT 60 lbs.
INVESTIGATIONS
TELEVISION
MAGNETOMETER
PLASMA PROBE
ION CHAMBER
RADIATION DETECTOR
COSMIC RAY TELESCOPE
DUST DETECTOR
OCCULTATION
POWER ≅ 310 WATTS @ MARS
STABILIZATION 3 AXIS
DESIGN LIFE 250 DAYS
LAUNCH VEHICLE ATLAS AGENA
MISSION MARS FLY-BY
ENCOUNTER MID-JULY 1965
NASA SL65-6
REV. 11-21-66

MARINER IV

Although the primary objectives of the Mariner IV mission were accomplished successfully with the July 14, 1965, fly-by of Mars, this spacecraft continued transmitting good interplanetary data until about October 1, 1965. At that time its transmitter was switched to the omnidirectional antenna because the geometry was such that the Earth would soon pass outside the beam of the fixed directional antenna on board the spacecraft.

The spacecraft was checked about once per month to assure that it was still operating. Activation of the 210 ft. radio telescope at Goldstone, California and the return of Mariner IV to feasible communication distance and position from Earth afford the unique opportunity to re-activate some of the on-board experiments as well as to carry out some newly-conceived experiments to take advantage of the position of the vehicle. Experimental data were acquired, starting in March 1966 and continuing to the present. If the spacecraft and its scientific instruments continue to operate properly, approximately six months of further interplanetary data should be obtainable during the period when the spacecraft is near opposition.

In March-April 1966 a solar occultation experiment was accomplished which involved a unique series of measurements of the solar corona. During the same period solar plasma measurements were taken at a time when Mariner IV and Pioneer VI, carrying similar instrumentation, were on opposite sides of the Sun.

During the time when the spacecraft is at or near opposition, with a closest approach to Earth of about 25 million miles, the following investigations may be conducted:

1. Measure the interplanetary magnetic field, using a sensitive 3-axis helium magnetometer.

E. J. Smith
Jet Propulsion Laboratory

P. J. Coleman, Jr.
University of California, Los Angeles

L. Davis, Jr.
California Institute of Technology

D. E. Jones
Brigham Young University and Jet Propulsion Laboratory

2. Measure the character of the interplanetary plasma including flux, energy, and direction of protons.

H. S. Bridge
Massachusetts Institute of Technology

A. J. Lazarus
Massachusetts Institute of Technology

C. W. Snyder
Jet Propulsion Laboratory

3. Determine flux and energy spectrum of low-, medium-, and high-energy protons and alpha particles, using silicon solid-state detectors.

J. A. Simpson
University of Chicago

J. O'Gallagher
University of Chicago

4. Study the angular distributions, energy spectra, and time histories of solar cosmic rays and energetic electrons in interplanetary space.

J. A. Van Allen
University of Iowa

L. A. Frank
University of Iowa

S. M. Krimigis
University of Iowa

5. Measure flux, direction, mass and velocity distribution of micrometeorites in interplanetary space.

J. L. Bohn
Temple University

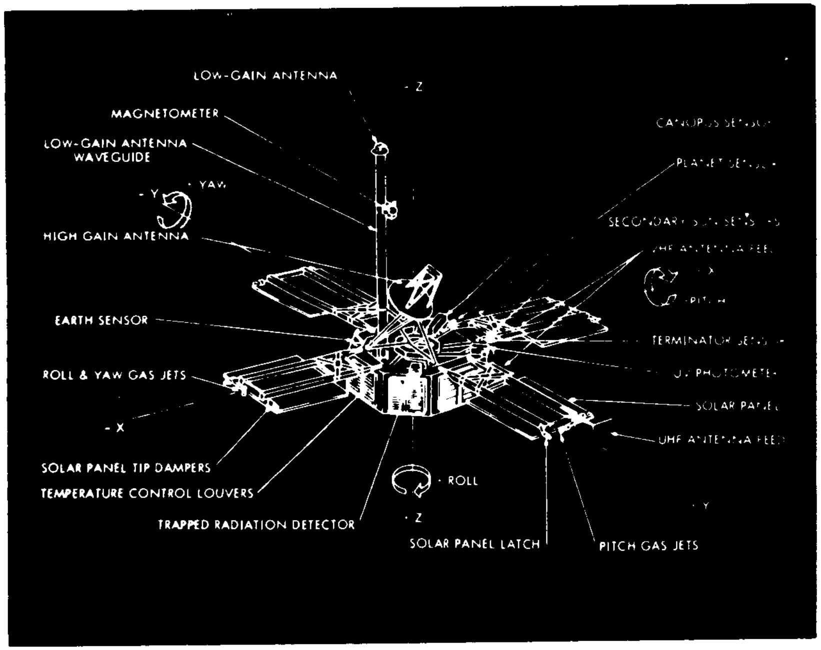
W. M. Alexander
Temple University

O. E. Berg
Goddard Space Flight Center

C. W. McCracken
Goddard Space Flight Center

L. Secretan
Goddard Space Flight Center

MARINER VENUS-1967



GROSS WEIGHT	550 LBS.
INSTRUMENT WEIGHT	32 LBS.

INVESTIGATIONS

RADIATION DETECTORS	UV PHOTOMETER
MAGNETOMETER	CELESTIAL MECHANICS
PLASMA PROBE	S-BAND OCCULTATION

DUAL FREQUENCY RADIO PROPAGATION

POWER	$\simeq$ 350 WATTS @ EARTH
DESIGN LIFE	140 DAYS
LAUNCH VEHICLE	ATLAS AGENA
MISSION	VENUS FLYBY
ENCOUNTER	OCTOBER 1967

NASA HQ SP 67-15367
11-19-67

MARINER VENUS 1967

The primary objective of the Mariner 1967 Project is to conduct a flyby mission to Venus in 1967 in order to obtain scientific information which will complement and extend the results obtained by Mariner II relevant to determining the origin and nature of Venus and its environment.

The secondary objectives are to acquire engineering experience in converting and operating a spacecraft designed for a Mars mission into one flown to Venus, and to obtain information on the interplanetary environment in the region between the orbits of Earth and Venus during a period of increasing solar activity.

It is planned to launch the Mariner Venus spacecraft in June 1967 and to fly a type-I trajectory to encounter Venus in mid-October 1967.

The following investigations will be conducted:

1 Measure the density and distribution of atomic hydrogen and atomic oxygen and the temperature of the outer atmosphere of Venus, using ultraviolet photometers (1080 to 1800 Å and 1250 to 1800 Å).

C. A. Barth	University of Colorado
J. B. Pearce	University of Colorado
K. K. Kelly	University of Colorado
E. F. Mackey	Packard-Bell Electronics
L. Wallace	Kitt Peak National Observatory
W. G. Fastie	Johns Hopkins University

2 Measure the scale height and density distribution of the Venus atmosphere and ionosphere using the phase shift and refractive defocussing attenuation of the S-band telecommunication signal as the spacecraft enters and exits occultation behind Venus.

A. Kliore	Jet Propulsion Laboratory
D. L. Cain	Jet Propulsion Laboratory
G. S. Levy	Jet Propulsion Laboratory
S. I. Rasool	Institute for Space Studies, Goddard Space Flight Center
G. Fjeldbo	Stanford University

3 Obtain information on the neutral atmosphere and ionosphere of Venus and make possible separation of dispersive plasma effects from the non-dispersive effects of the neutral components of the atmosphere, using 50 and 425 MHz radio transmissions from Earth, measured and processed in the spacecraft telemetry system.

V. R. Eshleman	Stanford University
G. Fjeldbo	Stanford University

H. T. Howard	Stanford University
B. B. Lusignan	Stanford University
A. M. Peterson	Stanford University
R. L. Leadabrand	Stanford Research Institute
R. A. Long	Stanford Research Institute

4 Determine occurrence and measure intensity and energy spectra of energetic particles in interplanetary space and their angular distribution; conduct an improved search for a trapped radiation belt around Venus. Will use geiger mueller tubes and a solid state detector.

J. A. Van Allen	University of Iowa
L. A. Frank	University of Iowa
S. M. Krimigis	University of Iowa

5 Determine the magnetic field strength and direction in interplanetary space and in the close vicinity of Venus, using a low field helium triaxial magnetometer.

E. J. Smith	Jet Propulsion Laboratory
P. J. Coleman	University of California, Los Angeles
L. Davis	California Institute of Technology
D. E. Jones	Brigham Young University and Jet Propulsion Laboratory

6 Measure flux, energy, and direction of arrival of solar plasma protons in the 10 ev to 10 kev energy range, using Faraday cup detectors.

H. S. Bridge	Massachusetts Institute of Technology
A. J. Lazarus	Massachusetts Institute of Technology
C. W. Snyder	Jet Propulsion Laboratory

7 Obtain improved determinations of the masses of Venus and the Moon and the astronomical units, and the ephemerides of Earth and Venus, using the DSN tracking data.

J. D. Anderson	Jet Propulsion Laboratory
L. Efron	Jet Propulsion Laboratory
G. E. Pease	Jet Propulsion Laboratory
R. C. Tausworthe	Jet Propulsion Laboratory

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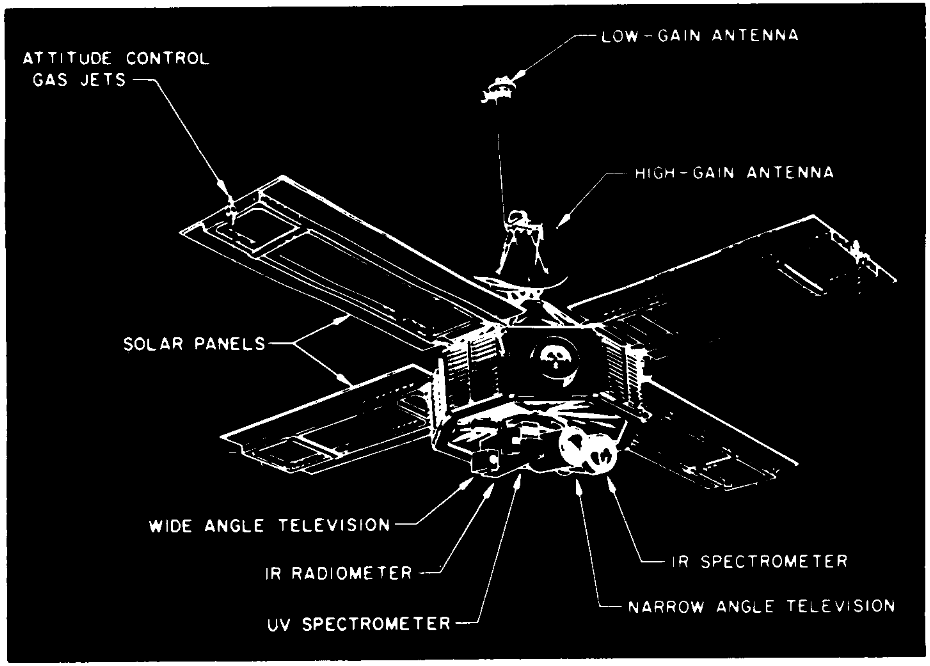
MARINER MARS – 1969



GROSS WEIGHT	800 LBS.
INSTRUMENT WEIGHT	80 LBS.
INVESTIGATIONS	
TELEVISION	UV SPECTROMETER
IR RADIOMETER	IR SPECTROMETER
OCCULATION	CELESTIAL MECHANICS
POWER	$\leq$ 450 WATTS @ MARS
STABILIZATION	3 AXIS
DESIGN LIFE	207 DAYS
LAUNCH VEHICLE	ATLAS CENTAUR
MISSION	MARS FLYBY
ENCOUNTER	EARLY AUGUST 1969

NASA HQ SP67-15368
11-21-66

MARINER MARS 1969

The primary objective of the Mariner Mars 1969 project is to conduct flyby missions in order to make exploratory investigations of Mars which will set the basis for future experiments, particularly those relevant to the search for extraterrestrial life.

The secondary objective is to develop technology for the succeeding Mars missions.

It is planned to launch two Mariner spacecraft early in 1969 to fly by Mars in August 1969.

The following investigations will be conducted:

1. Record visual appearance of surface areas of Mars, determine general physiography over a portion of the planet, search for evidences of episodic geologic history and for micro-environments possibly suitable for existence of life, using an upgraded Mariner IV--type vidicon camera system with both high- and low-resolution optics.

R. B. Leighton	California Institute of Technology
B. C. Murray	California Institute of Technology
R. P. Sharp	California Institute of Technology
N. H. Horowitz	California Institute of Technology
J. D. Allen	Jet Propulsion Laboratory
A. G. Herriman	Jet Propulsion Laboratory
L. G. Malling	Jet Propulsion Laboratory
R. K. Sloan	Jet Propulsion Laboratory
M. Davies	RAND Corporation
C. Leouy	RAND Corporation

2. Identify and measure concentration of polyatomic molecules in the atmosphere of Mars; obtain information concerning surface composition, gas temperature, surface albedo and temperature, and atmospheric chemistry, using an optical wedge infrared spectrometer in the 1.5 to 15 micron range.

G. C. Pimentel	University of California, Berkeley
K. C. Herr	University of California, Berkeley

3. Determine the temperature of discreet areas of the surface of Mars coincident with TV coverage of the same areas, for correlation with visible features, using a two-channel infrared radiometer.

G. Neugebauer	California Institute of Technology
G. Münch	California Institute of Technology
S. C. Chase	California Institute of Technology

4 Identify and measure distribution of atoms, molecules, radicals, and ions in the upper atmosphere; estimate the pressure and scale height of the lower atmosphere, using an ultraviolet spectrometer with an occulting telescope.

C. A. Barth	University of Colorado
W. G. Fastie	Johns Hopkins University

5 Obtain improved knowledge of the masses of Mars and the Moon, the astronomical unit, and the ephemerides of Earth and Mars, using DSN tracking data of Mariner IV and Mariner Mars 1969.

J. D. Anderson	Jet Propulsion Laboratory

6 Obtain information on density, extent, and composition of the atmosphere and ionosphere, and the radius and physical oblateness of Mars, using phase shift and refractive defocussing attenuation of the S-Band spacecraft carrier signal.

A. J. Kliore	Jet Propulsion Laboratory
D. L. Cain	Jet Propulsion Laboratory
G. S. Levy	Jet Propulsion Laboratory

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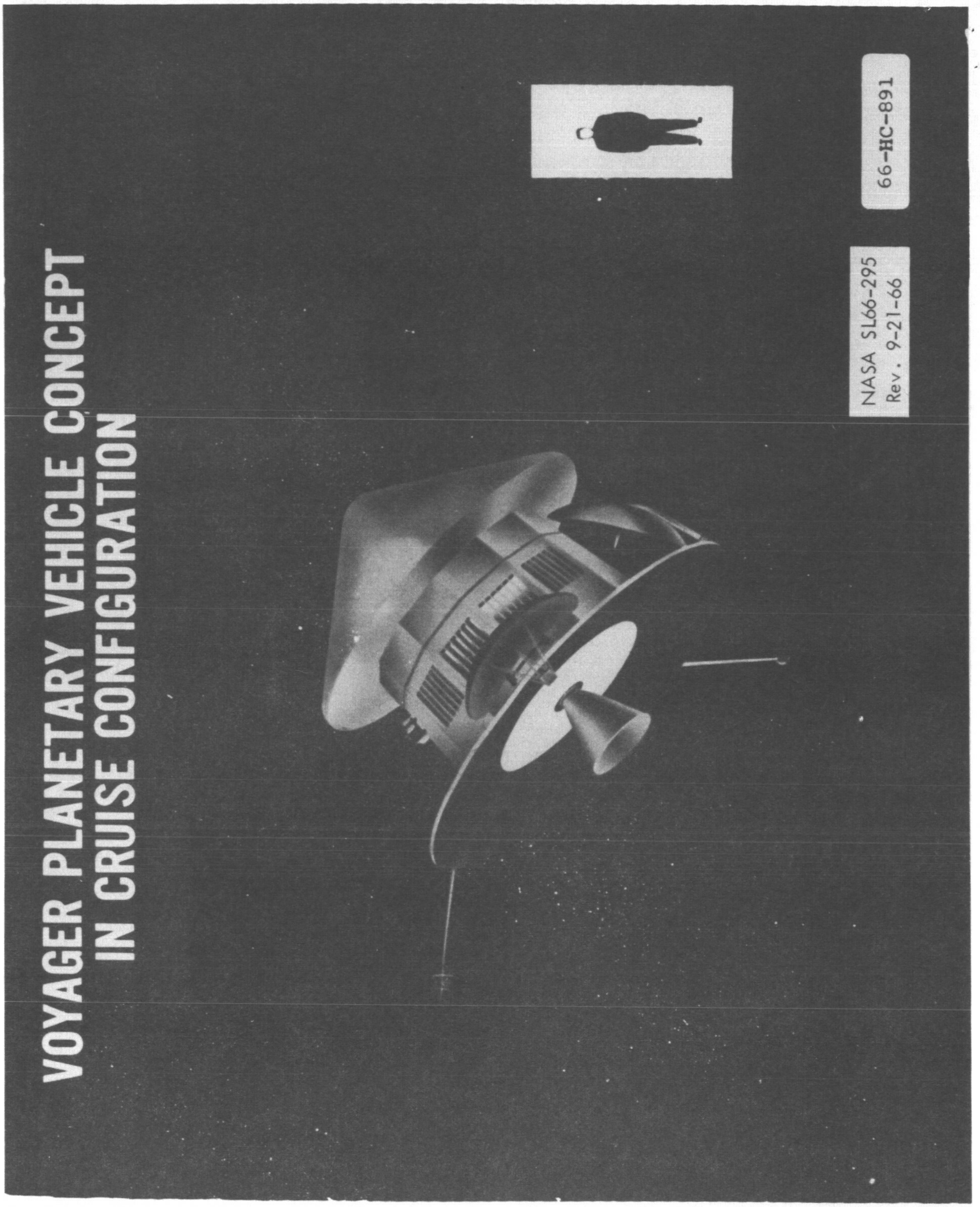


VOYAGER

The primary objective of the Voyager Project is to conduct scientific investigations of the solar system by instrumented, automated spacecraft which will fly by, orbit, and/or land on the planets. Emphasis will be placed on acquiring scientific information relevant to the origin and evolution of the solar system; the origin, evolution and nature of life; and the application of this information to an understanding of terrestrial life.

The first scheduled phase of the project is the exploration of Mars. The primary objective of the Voyager missions to Mars is to obtain information relevant to the existence and nature of extraterrestrial life; the atmospheric surface, and body characteristics of the planet; and the planetary environment, by performing experiments at the surface and in orbit about the planet.

A secondary objective is to further our knowledge of the interplanetary medium between the planets Earth and Mars by obtaining scientific and engineering measurements while the spacecraft is in transit.

It is presently planned to launch two Voyager planetary vehicles on a single Saturn V beginning with the 1973 opportunity. Each Voyager planetary vehicle will comprise an Orbiting Spacecraft System, and an Entry and Landing System which transports the Surface Laboratory and the Entry Science System. All missions will make scientific observations from orbit, during descent, and at the surface.

Voyager designs are based upon the concept that the basic structures and major subsystems shall accommodate, without major change, growth and evolution of the scientific payloads as insight is gained into the nature of the planet and more specific and complex experiments are conducted.

Preliminary design of the Orbiting Spacecraft System has been completed; system design will be completed by about December 1968 with experiment selection for the 1973 mission to be accomplished by July 1968.

The Orbiting Spacecraft will be instrumented for long-term remote observation of the planet and its space environment. Proposed areas for early experimentation are:

1. Planetary studies (gravitation, mapping in visible and infrared, topography, seasonal and diurnal variations, gamma ray and infrared spectroscopy, magnetic fields).

2. Atmosphere and environment studies (ionosphere sounding, air-glow studies, cosmic and solar radiation, atmospheric composition and distribution, circulation patterns).

During descent, the entry science instrumentation will derive atmospheric data generally as follows: pressure, density and temperature profiles, scale height and atmospheric composition.

The Surface Laboratory will establish direct contact with the planet and acquire data on the physical, chemical, and biological environment and activity. It must span a large number of scientific disciplines and must be responsive to change as knowledge of the planet increases. Proposed areas for early experimentation are:

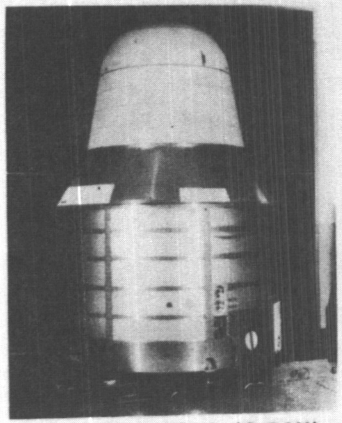
1. Biological studies (biological environment, detection of growth and metabolic activities, detection of organic molecules, visual examination both large scale and microscopic, biochemical processes, deviations from inorganic equilibrium).

2. Planetary studies (chemical composition and structure of the surface, detection of water past or present, intensity of cosmic and solar radiation, seismology, radioactivity).

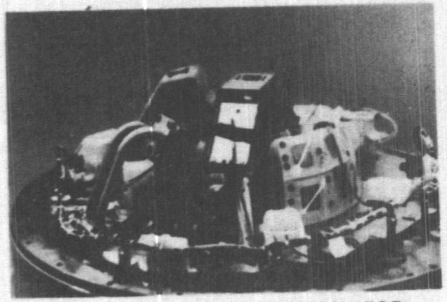
3. Atmosphere studies (chemical composition of atmosphere, temperature, wind velocity and direction, dust flux, diurnal variations, surface pressure).

BIOLOGICAL SATELLITES

BIOSATELLITE



BIOSATELLITE A (3-DAY)



RADIATION SUBASSEMBLY FOR BIOSATELLITE A
(Approx. 30" in diameter)

GROSS WEIGHT

IN ORBIT	950-1250 LBS.
ON PARACHUTE	285-325 LBS.

INVESTIGATIONS

WEIGHTLESSNESS, RADIATION
CIRCADIAN RHYTHMS

TIME IN ORBIT

3, 21 AND 30 DAYS

POWER

3-DAY BATTERIES
21-DAY AND 30-DAY
FUEL CELL PLUS BATTERIES

RECOVERY

AERIAL OR FROM WATER

LAUNCH VEHICLE

TWO-STAGE,
THRUST-AUGMENTED DELTA

ORBIT

CIRCULAR 170 TO 180 MILES
INCLINATION 33.5°

PLAN

SIX FLIGHTS, FIRST FLIGHT
LATE 1966

SP65-16321
Rev. 11-17-66

BIOLOGICAL SATELLITES

The Biosatellite Program is designed to study the effects on biological systems of the unique factors of the space environment. Among these are the effects of weightlessness, the effects of weightlessness combined with a known source of gamma radiation, and the removal of living systems from the direct influence of the Earth's periodicity. Living systems, exposed to simultaneous weightlessness and radiation, will be studied to determine if these environmental factors are synergistic (working together) or antagonistic or if they produce no significant effect compared with Earth laboratory controls.

The experiments to be conducted in the Biosatellite deal with biologic functions at the cellular, tissue, organ, and organism levels in a wide variety of plants and animals. The phenomena to be studied at the cellular and tissue levels include biochemical reactions, genetic changes, embryologic development, growth and integrated function. Physiologic function, behavior, and performance will be monitored in more highly developed organisms such as primates.

The radiation-weightlessness experiments involve plants, cells, and insects that will be exposed to precise doses of gamma radiation provided by an 85-strontium source. The radioactive source, enclosed in a tungsten-nickel-copper sphere, can be rotated to provide from 200 to 5000 Rads depending on the distance the experiments are located from the source over a period of three days in orbit. Duplicate control experiments will be in the spacecraft, but shielded from the radiation by a tungsten backscatter shield.

Circadian (24-hour) rhythms indigenous to the organism will be investigated. These rhythms, primarily changes in body temperature, body activity and food consumption, will be studied in rats. The hypothesis to be tested is whether the normal 24-hour behavior of these animals is affected by removing them from the Earth's environment and periodicity.

In the primate, *Macaca nemestrina* or the pig-tailed monkey, we want to determine the effects of weightlessness on: (1) the central nervous system; (2) the cardiovascular system; (3) the renal system; (4) general metabolism; (5) musculoskeletal metabolism, especially calcium mobility; and (6) behavior and performance.

Three missions are required to accommodate the experiment payloads. The missions are categorized by their nominal time in orbit and the objectives of the experiments. Each mission will have a backup.

The 3-day flight, Biosatellite A, and its backup Biosatellite B, will carry general biology experiments to determine effects on living organisms of the combination of radiation, weightlessness, and the absence of the Earth's rotation. The experiments include pepper and flowering plants, wheat seedlings, and beetles. Of the thirteen experiments selected, three of these, dealing with the development and growth of wheat seedlings, have been combined. Upon confirmation that Biosatellite A has achieved a successful orbit, the satellite will be designated as Biosatellite I. Biosatellite B will be launched approximately 3 months later in the event the first launch is not completely successful or in order to gather more statistical data from a repeat of the experiments flown in Biosatellite A. Biosatellite B will be a backup to Biosatellite A in the event a failure occurs immediately prior to launch.

The 21-day flight, Biosatellite C (Biosatellite E is its backup), will carry general biology experiments to determine the effects of weightlessness on plant morphogenesis, isolated human cells, gross body composition and function in mammals (rats), and circadian or 24-hour rhythms. Four experiments have been selected for flight.

The 30-day flight, Biosatellite D with Biosatellite F as a backup, will carry a pig-tailed monkey and experiments to determine the effects of weightlessness on the central nervous system and such functions as alertness, sleep-wakefulness, performance of coordination and discriminatory tasks, and fatigue; general metabolism; and cardiovascular function. Two experiments have been selected for this flight, one of which deals with the primate in flight, and the other is concerned with pre- and post-flight studies of calcium and other mineral mobilization and loss from bone.

Biosatellite Project personnel of the Ames Research Center are cooperating with and assisting the investigators in the engineering and design of experiment flight hardware, life support systems, and telemetry and data retrieval requirements. Experiment packaging and instrumentation have been developed and tested; and, in most instances, flight hardware is being fabricated. For the 3-day flight, Biosatellites A and B have been tested at the component and systems level, have been qualified for flight, and have been shipped to Kennedy Space Center in preparation for launch. The experiments, too, have been qualified.

The Biosatellite will be launched from Cape Kennedy by the two-stage, thrust-augmented Thor Delta launch vehicle. It will be placed into an orbit at a height consistent with the weightlessness requirements of the experiments, for example, about 180 nautical miles for the 30-day primate mission. The orbital inclination of 33.5° permits reception of telemetry data under most circumstances during each orbit at one of the following ground stations: Fort Myers, Florida; Lima, Peru; Quito, Equador; and Santiago, Chile. Telemetry data reception might be missed by the ground stations during one orbit, but no two orbits in succession will be missed.

The data will be transmitted by telemetry from the Biosatellite to the ground station during the three to five minutes the satellite is within range of the ground station. Data on preselected channels are separated and transmitted to the Control Center after each pass from the stations at Lima and Quito to enable personnel in the Control Center to assess the status of the spacecraft or experiments. Two minutes of the data train will be transmitted from Ft. Myers on a high-speed teletype line for immediate assessment while the station at Santiago will process and transmit three complete frames of data almost immediately following station pass. Conditions of vibration and acoustic environment will be telemetered to the ground during the powered boost phase. After engine cut-off such environmental data will be regularly recorded onboard. Up to 70 different commands may be sent in digital code to the spacecraft for control of the spacecraft functions.

The capsule portion of all the Biosatellites is designed to be recovered. The experiments are contained in the re-entry vehicle while various support equipment is located in the adapter section, which is separated from the re-entry vehicle prior to the retro maneuver. After re-entry into the sensible atmosphere, a drogue parachute is deployed followed by the main parachute. Shortly thereafter the heat shield is dropped. Air Force recovery aircraft will attempt to catch the capsule prior to impacting the water. In the event it is missed, alternative water recovery methods will be utilized. Recovery aids and life support equipment will function for a minimum of 6 hours. It is planned that the recovered capsule will be delivered to the laboratory at Hickam Air Force Base, Honolulu, within 6 hours for examination of the experiments.

Investigations and Investigators

Biosatellite A (B) (3-day flight)

General Biology experiments

1. Drs. S. W. Gray and B. F. Edwards (combined with P-1096 and P-1138)
   Emory University
   Atlanta, Georgia

Determine the effect of weightlessness on the growth and orientation of roots and shoots of wheat seedlings. (P-1020)

2. Dr. Charles J. Lyon (combined with P-1020) and P-1138)
Dartmouth College
Hanover, New Hampshire

Determine the effects of zero gravity on the emergence of wheat seedlings. (P-1096)

3. Drs. H. M. Conrad and S. P. Johnson (combined with P-1020 and P-1096)
Space and Information Systems Division
North American Aviation, Inc.
12214 Lakewood Boulevard
Downey, California

Determine the effects of weightlessness on the orientation of roots and shoots of wheat seeds. (P-1138)

4. Dr. Richard Young
Ames Research Center
Moffett Field, California

Determine the effects on cell fertilization and development of the frog egg in a gravity-dependent system. (P-1047)

5. Drs. J. C. Finn and S. P. Johnson
North American Aviation Space and Information Division
Torrence, California

Determine the effects of weightlessness on plant growth through measurements of the angle between leaf and stem of a pepper plant which is controlled by the plant hormone, auxin. (P-1017)

6. Dr. Richard W. Price
Colorado State University
Fort Collins, Colorado
and
Dr. D. E. Ekberg
General Electric Company
Philadelphia, Pennsylvania

Study in the amoeba (Pelomyxa carolinensis) the effects of zero gravity on the orderly synchronous division of nuclei and on the formation of food vacuoles and utilization of ingested nutrients. (P-1035)

Radiation Experiments

7. Dr. J. V. Slater
University of California
Berkeley, California

Examine the effects of radiation and zero gravity on embryonic differentiation and development of the pupae of Tribolium (flour beetle). (P-1039)

8. Dr. I. I. Oster
Bowling Green, Ohio

Larvae of Drosophila (fruit fly) which have newly hatched from eggs will be studied following recovery to learn of the effects of radiation and zero gravity on the rapidly growing cells of the larvae as they hatch into adults. (P-1160)

9. Drs. E. Altenberg and L. Browning
Rice University
Houston, Texas

Determine the effects of zero gravity on radiation-induced damage (mutation and chromosome breaking) in mature reproductive cells of a known genetic strain of female Drosophila previously mated with known genetic males. (P-1159)

10. Drs. A. H. Sparrow and L.A. Schairer
Brookhaven National Laboratory
Upton, New York

Determine the influence of radiation and zero gravity on mutation processes in budded stalks of Tradescantia (blue-flowering plant) by observing induced color changes. (P-1123)

11. Dr. R. C. Von Borstel
Oak Ridge National Laboratory
Oak Ridge, Tennessee
and
Dr. D. S. Grosch
North Carolina State of the
University of North Carolina
Raleigh, North Carolina

Male Habrobracon (parasitic wasps) will be exposed to several levels of radiation during zero gravity. Post-flight, they will be mated to evaluate the extent of genetic changes. (P-1079)

12. Dr. F. J. DeSerres
Oak Ridge National Laboratory
Oak Ridge, Tennessee

Determine the chromosomal mutations in Neurospora (bread mold) following exposure to a known gamma source during zero gravity. (P-1037)

13. Dr. R. H. T. Mattoni
NUS Corporation
Hawthorne, California
and
Drs. W. T. Romig and W. T. Ebersold
University of California
Los Angeles, California

Slowly growing lysogenic bacteria (Escherichia coli) will be exposed simultaneously to zero gravity and radiation to determine whether or not viruses can proliferate within irradiated bacteria under zero gravity. (P-1135)

Biosatellite C (E) (21-day flight)

1. Dr. A. H. Brown
University of Pennsylvania
Philadelphia, Pennsylvania
and
Dr. Orville Dahl
University of Minnesota
Minneapolis, Minnesota

Study plant morphogenesis under weightlessness in a small terrestrial angiosperm (Arabidopsis) to determine whether growth differs qualitatively and quantitatively from plants grown in the Earth's gravitational field. (P-1003)

2. Dr. G. C. Pitts (combined with P-1093)
University of Virginia
Charlottesville, Virginia

Determine the effect of weightlessness on gross body composition and metabolism with special reference to atrophy of skeletal muscle and bone, which results from disuse, and to determine patterns of energy expenditure. (P-1145)

3. Dr. F. Halberg (combined with P-1145)
University of Minnesota
Minneapolis, Minnesota

Obtain baseline data on periodicity in rodents relative to Biosatellite experiments on circadian rhythms. (P-1093)

4. Dr. P. O'B. Montgomery
University of Texas
Southwestern Medical School
Dallas, Texas

Determine zero gravity influences on isolated human cells to observe capacity of cell to maintain its membrane to undergo normal mitotic cycles, and to perform normal biochemical and physiologic functions. (P-1084)

<u>Biosatellite D (F)</u> (30-day flight)

1. Dr. W. R. Adey
University of California
Los Angeles, California;

Dr. J. P. Meehan
University of Southern California
Pasadena, California;

Dr. J. H. Rho
Jet Propulsion Laboratory
Pasadena, California;

and

Dr. N. Pace
University of California
Berkeley, California

Monitor brain functions and performance and cardiovascular and metabolic activities in the primate under prolonged weightlessness. (P-1001)

2. Dr. P. B. Mack
Texas Woman's University
Denton, Texas

Investigate losses of bone mineral (calcium) in primates due to immobilization during prolonged weightlessness through radiographic bone densitometry and intensive biochemical analyses pre- and post-flight, as well as analyses of excreta collected during flight. (P-1062)

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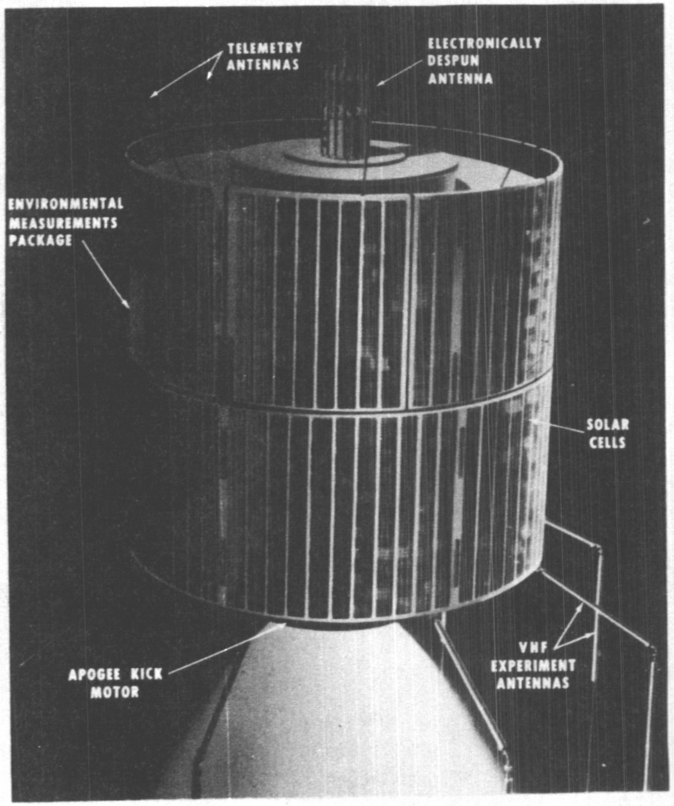
SPACE APPLICATIONS

APPLICATIONS TECHNOLOGY SATELLITE
ATS-B



LAUNCH WEIGHT	697 KG
EXPERIMENTS	14
POWER	148 WATTS
STABILIZATION	SPIN
DESIGN LIFE	3 YEARS
LAUNCH VEHICLE	ATLAS/AGENA & APOGEE KICK MOTOR
ORBIT	SYNCHRONOUS, GEOSTATIONARY
STATUS	LAUNCH SCHEDULE 4TH QTR 1966

NASA SP65-16318
Rev. 11-17-66

APPLICATIONS TECHNOLOGY SATELLITES

The Applications Technology Satellites (ATS) Project consists of five flights to test promising technology that is common to a number of satellite applications, and to conduct various space environmental investigations. ATS-B, the first of the series, is scheduled for launch late in 1966, to be followed by ATS-A in the second quarter of 1967. C, D, and E are scheduled in that order for launch in 1968 and 1969.

The ATS-B and C spacecraft are of similar design. Both will be spin stabilized in geostationary orbits. The ATS-A, D and E spacecraft will be gravity gradient stabilized with ATS-A in a 11,000 km orbit and ATS-D and E in geostationary orbits. The D and E spacecraft are similar to the A spacecraft except that an apogee kick motor is added for the two synchronous altitude missions.

Descriptions of the experiments are listed below:

ATS-B

1. Communications -- a microwave dual mode transponder and an electronically despun antenna will permit investigations of multiple access in the SSB/PM mode and of wideband color TV transmissions in the FM/FM mode. Hughes Aircraft Company

2. VHF Transponder -- an FM/FM transponder will be used for experiments involving voice and data communications between aircraft and ground stations. Hughes Aircraft Company

3. Meteorological TV -- a high resolution spin scan camera system will obtain cloud pictures from synchronous altitude. University of Wisconsin/V. E. Suomi

4. Nutation Sensor -- two sensitive accelerometers will detect nutation as small as one-thousandth of a degree. GCA Corp

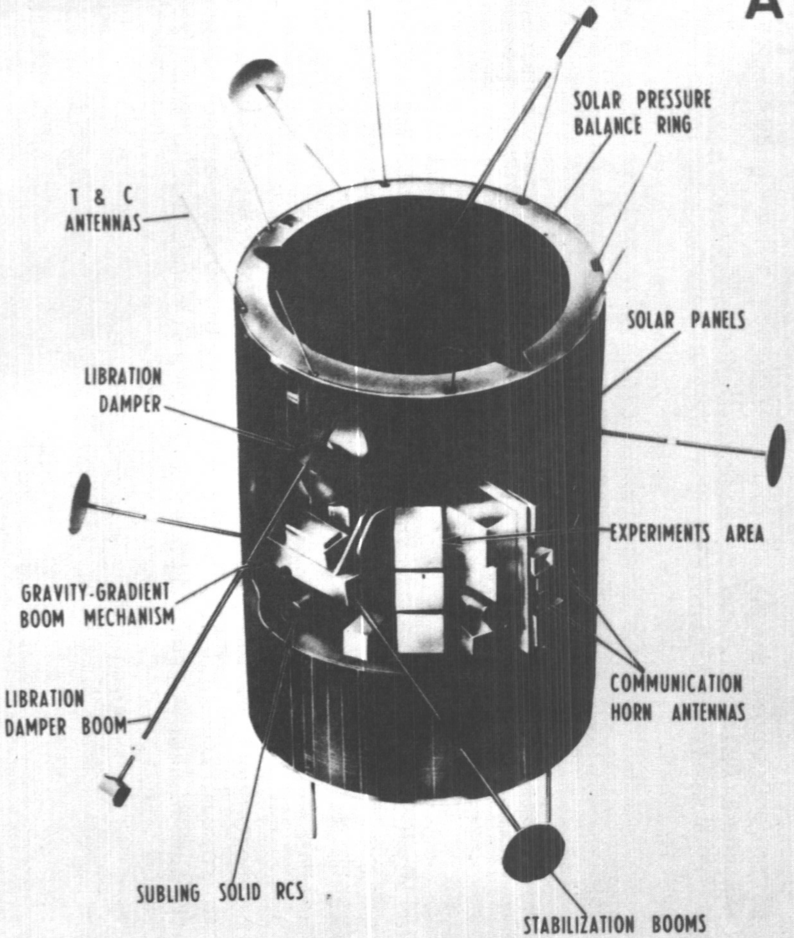
5. Resisto-Jet Thruster -- a light-weight, low-thrust device will be evaluated for satellite inversion application. Lewis Research Center

6. Magnetic Field Measurements -- fluxgate magnetometers will permit field strength determinations. UCLA/P. J. Coleman, Jr.

7. Thermal Coating Degradation -- effect of exposure to synchronous altitude environment on various thermal coatings will be determined. Goddard Space Flight Center/J. J. Triolo

APPLICATIONS TECHNOLOGY SATELLITE

ATS-A



LAUNCH WEIGHT	315 KG
EXPERIMENTS	12
POWER	139 WATTS
STABILIZATION	GRAVITY GRADIENT
DESIGN LIFE	3 YEARS
LAUNCH VEHICLE	ATLAS/AGENA
ORBIT	11,000 KM CIRCULAR 28° INCLINATION
STATUS	LAUNCH SCHEDULED FOR 2ND QTR 1967

NASA SP65-16320
Rev. 11-17-66

8. Solar Cell Degradation -- radiation damage measurements of various shielded solar cells will be obtained. Goddard Space Flight Center/R. C. Waddel

9. Electron Content of the Ionosphere -- ground station measurements at VHF frequencies will be used to determine propagation characteristics and electron density of the ionosphere. Stanford University/O. K. Garriott

10. Energetic Particle Measurements --

	Electrons	Protons	Alpha Particles
a. Rice University/ J. W. Freeman, Jr. M. M. McCants D. T. Young	--	0.25 - 50 ev	0.25 - 50 ev
b. University of Minnesota/ J. R. Winckler R. Arnoldy	50 Kev - 1 Mev	--	--
c. Bell Telephone Labs/ W. L. Brown C. S. Roberts	300 Kev - 1 Mev > 1.0 Mev	0.7 - 100 Mev	1.8 - 85 Mev
d. Aerospace Corporation/ G. A. Paulikas S. C. Freden J. B. Blake	0.2 - 2 Mev > 2.0 Mev	5 - 55 Mev	--

ATS-A

1. Communications -- microwave transponder together with horn antennas will permit investigations of multiple access SSB/PM and of wideband FM/FM modes. Hughes Aircraft Company

2. Gravity Gradient Stabilization -- four 40 meter booms will provide spacecraft stabilizing torques and two 13 1/2 meter damper booms will be attached to two interchangeable passive dampers. General Electric Company

3. Meteorological TV -- two cameras for cloud cover observations, one high-resolution and the other wide-angle, will be used together with the Nimbus-type recorder. Radio Corporation of America

4. Earth's Albedo -- sensors will be employed for obtaining earth background data. Department of Defense

5. Thermal Coating Degradation -- effect of medium altitude space environment on various thermal coatings will be determined. Goddard Space Flight Center/J.J. Triolo

6. Solar Cell Degradation -- radiation damage measurements of various shielded solar cells will be obtained. Goddard Space Flight Center/R. C. Waddel

7. Cosmic Radio Noise -- integrated radio noise measurements from 250 Kc/s to 2.5 Mc/s will be made. Goddard Space Flight Center/ R. G. Stone, J. K. Alexander

8. Electric Fields -- electrometers will be used to measure ambient magnetospheric electric fields. Goddard Space Flight Center/ T. Aggson, J. P. Heppner

9. VLF Power Spectrum -- electromagnetic radiation measurements will be made between 5 and 45 Kc/s. Bell Telephone Laboratories/ C. S. Roberts

10. Energetic Particle Measurements --

		Electrons	Protons	Alpha Particles
a.	University of Minnesota/ J. R. Winckler R. Arnoldy	50 Kev - 1 Mev	--	--
b.	University of California at San Diego C. E. McIlwain J. Valerio	$>$0.5 Mev $>$1.0 Mev	$>$12 Mev $>$20 Mev	--
c.	Bell Telephone Laboratories W. L. Brown	0.5 - 1.0 Mev $>$1 Mev	0.7 - 100 Mev	1.8 - 85 Mev

ATS-C

1. Communications -- a microwave transponder, with multiple access SSB/PM and wideband FM/FM modes (Hughes Aircraft Company), and a mechanically despun (Earth pointing) antenna (Sylvania Electric Company) will be used in communications research.

2. VHF Transponder -- The same transponder as on ATS-B will be used to permit further experiments between aircraft and ground, and also experiments in a position determination using the Navy Omega Position Location Experiment system (OPLE).

3. Meteorological TV -- Spin scan camera; the same as on ATS-B, with the addition of a three-color capability. (U. Wisconsin)

4. Self-Contained Navigation Experiment -- to determine the orbit of the spacecraft solely by tracking the trajectory of an ejected particle against the star background. Control Data Corporation

5. Reflectometer Experiment -- to determine reflectance degradation of various optical reflector samples in the space environment.
Electro-Optical Systems

6. Image Dissector Camera -- to use spin for East-West scan and electronic deflection of North-South scan, to investigate technology of cloud observation from synchronous altitude.
Goddard Space Flight Center/G. Branchflower

ATS-D

1. Communications -- microwave transponder with multiple access SSB/PM and wideband FM/FM modes together with planar array antennas.
Hughes Aircraft Company

2. Gravity Gradient Stabilization -- four 133-foot booms to provide spacecraft stabilizing torques and two 45-foot damper booms attached to two interchangeable passive dampers.
General Electric Company.

3. Meteorological TV -- day/night camera using image orthicon with sufficient dynamic range to permit nighttime as well as daytime observations.
Hazeltine Corporation

The experiment complement for ATS-E has not been selected.

COMMUNICATIONS PROGRAM

The ECHO, RELAY and SYNCOM projects have been completed. Of these, ECHO I and II, RELAY II, and SYNCOM II and III are still operable and capable of usage.

These experimental satellites have clearly demonstrated the basic feasibility of using satellites for point-to-point communications. The successful execution of ECHO, RELAY, and SYNCOM have made possible the beginnings of an operational capability. Intelsat I, the first operational commercial satellite, utilizes technology which was successfully demonstrated on SYNCOM satellites.

The basic objectives of the communications program are:

- To ensure that technology required for the establishment of future communications satellite systems is developed,

- To study the requirements for and technically assess the applicability of satellites to the future needs of communications systems, and

- To fulfill NASA's responsibilities under the Communications Act of 1962.

To meet these objectives, it is necessary for NASA to conduct a continuing program of supporting research and advanced mission studies, as well as to perform certain flight experiments.

To this end, the main thrust of NASA's communications research effort is directed toward advanced techniques for bringing satellite communications to an ever increasing number of small, perhaps mobile, users having multiple accessibility to the satellite system; toward broadcast satellite applications, both radio and television; toward more efficient techniques of frequency utilization through investigation of millimeter wavelengths; and toward satellite aids to lunar, planetary and interplanetary communications.

In the advanced missions area, NASA is currently studying the technical and cost factors that affect the feasibility of satellites capable of transmitting aural program material directly to FM radios and HF short-wave receivers. These studies are aimed at obtaining feasible spacecraft configurations, the technology requirements for such satellites, and the definition of a research and development program plan. Studies will be conducted on satellites capable of transmitting television program material to community and educational facilities, and to conventional home TV receivers. These studies are aimed at obtaining technical and cost data applicable to a full range of possible broadcast applications. A study of the technical and cost factors that affect the reception of television transmissions from synchronous satellites has been completed. The results of the latter study and the TV broadcast satellite mission studies will be useful in determining system characteristics optimized for specific user applications.

During fiscal year 1967, mission studies will be initiated for lunar communications relay satellites to support point-to-point communication needs on the lunar surface and for spacecraft-to-spacecraft communications to support landing and docking maneuvers on the far side of the Moon. A study of communications satellite relays in orbit about Mars will be initiated also for the expeditious relay of data from lander capsules on the Martian surface, and possibly as a tracking aid to future Mars orbiter and lander missions. A deep space communications system comparison and trade-off study, now under way, will provide parametric data for communications systems - considering the use of microwave, millimeter wave and optical frequencies.

EARTH RESOURCES SURVEY PROGRAM

The over-all objectives of the Earth Resources Survey Program are to determine those Earth resource data which can be acquired best from space and to develop the scientific and technological capabilities for the acquisition and utilization of such data. Five broad areas related to the Earth's resources have been identified as potentially suitable for the applications of space technology: Agricultural and forestry resources; geology and mineral resources; hydrology and water resources; geography, cartography, and cultural resources; and oceanography and marine resources. The Departments of Agriculture, Interior, and Navy are working directly with NASA to ensure that the data acquired from space are both useful and employable in assisting them in carrying out their responsibilities in the various resource fields.

Aircraft Program

Data are being obtained by utilizing a number of airborne electronic and electro-optical remote sensors over specific geographical areas of interest to geoscientists. These areas are being intensively studied to provide "ground truth" which permits the correlation of remote sensor data with actual conditions in the area and the interpretation of the features--agricultural, geologic, and so forth--by means of the sensor data. Data obtained from Nimbus and Gemini are also being used and interpreted. These studies are being conducted by scientists and engineers in NASA and other Federal agencies, universities, research institutions, and private industries. In addition to the full-time use of Convair 240A and a Lockheed P-3A, a number of other aircraft belonging to various agencies and institutions are being used on a part time basis to acquire data for the Earth Resources Survey Program.

Convair 240A - Instrumentation of this aircraft was initiated in October 1964, and initial survey operations over geologic test sites got under way in early December 1964. This aircraft has a maximum altitude of 6100 meters. The first flights carried only the camera systems; other instruments were installed as they became available. The aircraft is now scheduled to its full capability of sensors.

Lockheed P-3A (Electra) - This aircraft was acquired in December 1965, and is being instrumented for operations which are scheduled to begin in November 1966. This aircraft is ideally suited as a remote sensor aircraft for altitudes up to 12,200 meters. The aircraft has both a large cabin area and a bomb-bay area with a number of radomes and instrument-mounting provisions in which to install sensor systems and other experiments.

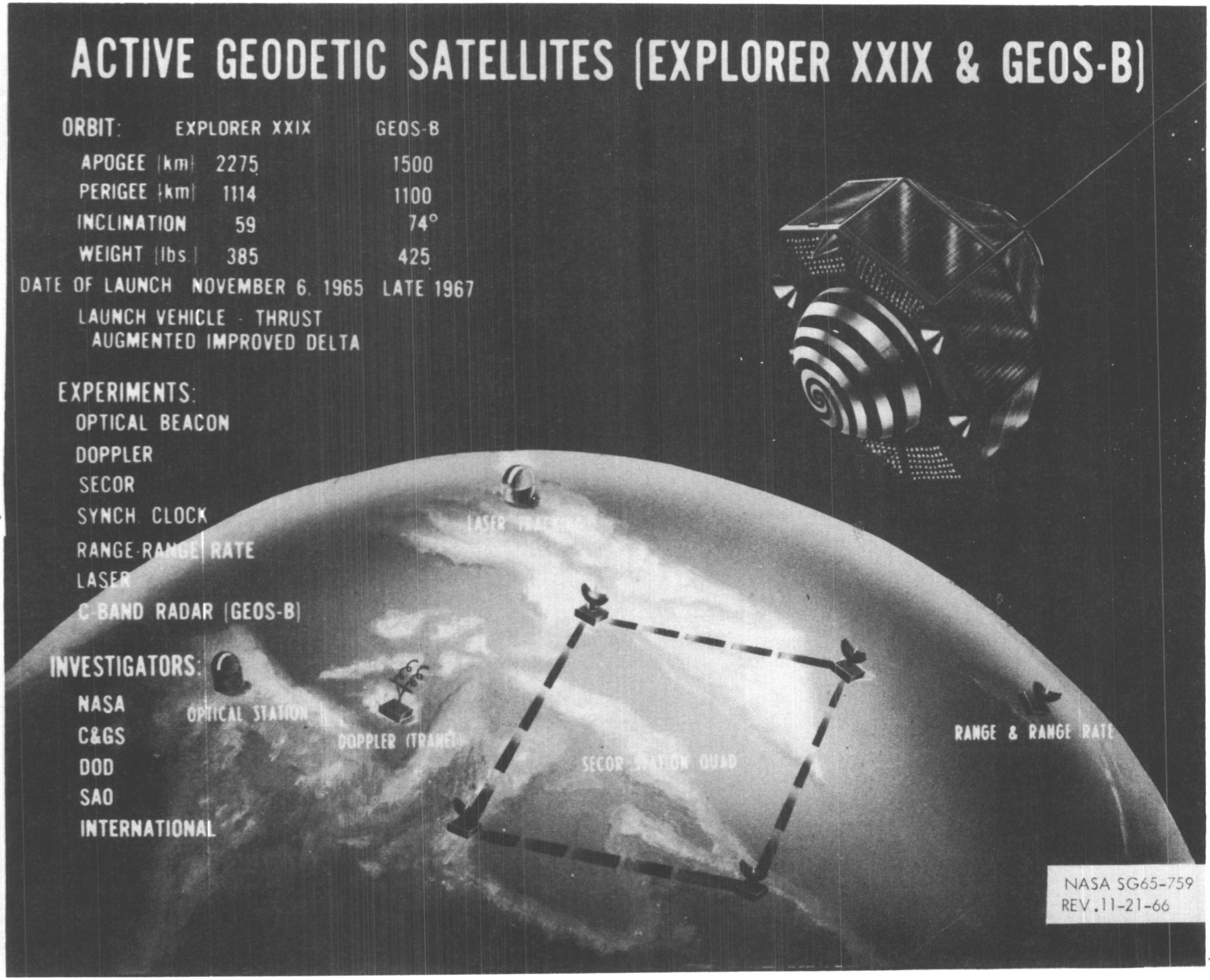
It also contains much of the basic instrumentation required for sensor operation, data correlation, and navigation of the aircraft. With installation of an auxiliary power unit, operation without the use of ground-based support equipment will be possible.

The following remote-sensing instruments are in use: The RC8 camera operates in the spectral range from 0.4 to 0.7 microns, using 9-inch film with a resolution of one foot at 3,000 feet altitude and a field of view of 74 degrees. The ITEK 9-lens, multiband camera operates from near UV to near IR using 70-millimeter film with a resolution of one foot at an altitude of 3,000 feet and a field of view of 18 degrees. The Reconofax IV single-channel, lateral-IR scanning system operates from 8 to 13 microns using 70-millimeter film. The University of Michigan wide-range spectral scanner employs 18 channels in the spectral range 0.4 to 13 microns with an horizon-to-horizon sweep. The Westinghouse AN/APQ 97 (XE-1) side-looking radar imager operates in the X-band using 9-inch film.The Philco DPD-2, K-band, unfocused side-looking radar imager, using a 10-degree beam width, is also available. Two radar scatterometers are under test. The Ryan REDOP operates at 13 GHz and the LFE SPECTRAC APN 131-A Doppler radar operates at 10 GHz, both using magnetic tape. For passive microwave imaging, the Autonetics geological radiometric mapper at 9 GHz is available with 70-millimeter film. Aircraft tests of passive UV imagery have employed the AAS-5, two-channel lateral-scanning system in the range 2,900 to 4,000 Angstroms with 35-millimeter film.

Spacecraft Program

During the 1970 to 1975 period the first spaceflight missions with the primary objective of acquiring data for Earth resources surveys are planned to include at least two flights (B and D) in the Apollo Applications Program (AAP). These will be manned spacecraft capable of carrying a sizable number of sensors which can be directed at selected parts of the Earth. On these initial space flights, coverage will be concentrated over areas such as the United States where ground controls will be used to verify the conclusions derived during the feasibility stage. Also during this time period it is expected that several unmanned Earth Resource Satellites will be flown, varying in size from 500 kilograms to 11,000 kilograms. In-house studies relative to these spacecraft have been initiated.

The following remote sensor instruments, based on the state of the art, are among those that may be used to provide an integrated, multispectral survey of Earth resources from space: Metric, panoramic, and multiband synoptic cameras; multispectral tracking telescope; radar imager; radar altimeter/spectrometer; wide-range spectral scanner; IR radiometer/spectrometer; microwave imager and radiometer; laser altimeter/scatterometer; magnetometer; gravity gradiometer; absorption spectroscope; chirp radar; viewfinder; and ultraviolet spectrometer-imager. In addition, Earth-based sensors are planned, which may include a number of fixed and mobile instruments, such as buoys, seismographs, stream gauges, and so forth, placed on or near the Earth's surface for detecting, recording, and transmitting a variety of Earth resources phenomena.


ACTIVE GEODETIC SATELLITES (EXPLORER XXIX & GEOS-B)
ORBIT: EXPLORER XXIX GEOS-B
APOGEE (km) 2275 1500
PERIGEE (km) 1114 1100
INCLINATION 59 74°
WEIGHT (lbs.) 385 425
DATE OF LAUNCH NOVEMBER 6, 1965 LATE 1967
LAUNCH VEHICLE - THRUST AUGMENTED IMPROVED DELTA
EXPERIMENTS:
OPTICAL BEACON
DOPPLER
SECOR
SYNCH CLOCK
RANGE-RANGE RATE
LASER
C-BAND RADAR (GEOS-B)
INVESTIGATORS:
NASA
C&GS
DOD
SAO
INTERNATIONAL
LASER TRACKING
OPTICAL STATION
DOPPLER (TRANET)
SECOR STATION QUAD
RANGE & RANGE RATE
NASA SG65-759
REV.11-21-66

GEOS AND PAGEOS

The objectives of the National Geodetic Satellite Program are (1) to develop a unified world datum (control points to 10 meters in geocentric coordinate system), (2) to improve the description of the Earth's gravitational field (spherical harmonic representation to $J_{15, 15}$), and (3) to compare and correlate the geodetic instrumentation systems being used. The Department of Commerce, the Department of Defense, and NASA are the main participants in the program which comprises both active and passive satellites. Their efforts are supplemented by those of SAO and the international community.

The first active geodetic satellite, Explorer XXIX, was launched on November 6, 1965, into an Earth orbit with an apogee of 2,275 km, a perigee of 1,114 km and an inclination of 59°. GEOS-B is planned for launch at the end of CY 1967 into a 1,500 by 1,100 km orbit, inclined 74°. The international geodetic community is participating in the observations.

The active geodetic satellites are utilizing the following geodetic systems:

1. Optical beacon (using PC-1000, BC-4, Baker-Nunn and other camera systems)

2. Doppler

3. SECOR

4. Passive satellite triangulation (same camera systems as in 1 above)

5. Range and range rate (S-Band)

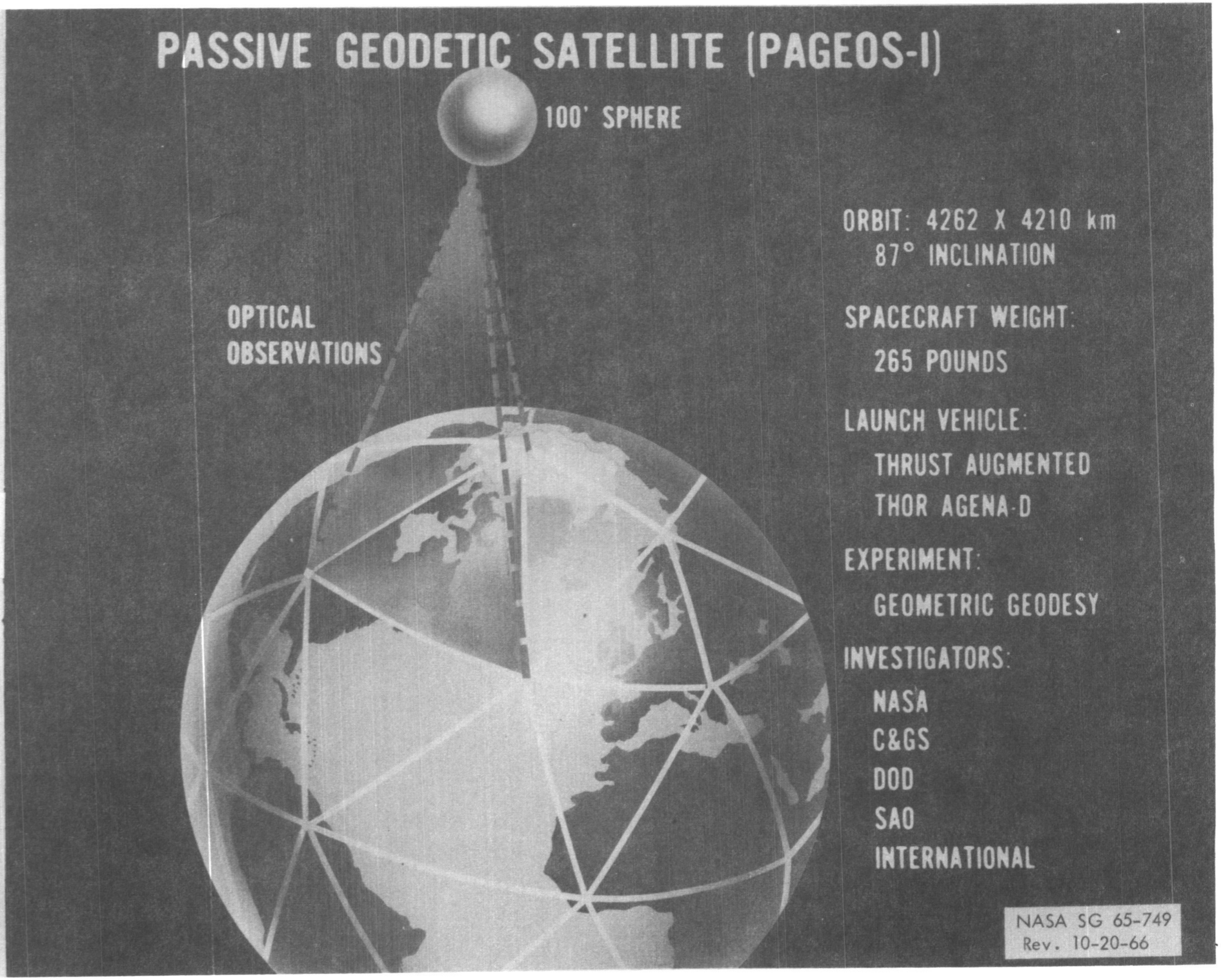
6. Laser reflector tracking

7. C-Band radar (on GEOS-B only, for evaluation as first-order geodetic system)

The passive geodetic satellite, PAGEOS-I, was launched on June 24, 1966, into an Earth orbit with an apogee of 4,262 km, a perigee of 4,210 km and an inclination of 87°.

The passive geodetic satellite is utilized in triangulations to derive a figure of the Earth with a minimum of hypotheses about gravity or the local vertical.

239-359 O - 66 - 9


PASSIVE GEODETIC SATELLITE (PAGEOS-I)
100' SPHERE
OPTICAL
OBSERVATIONS
ORBIT: 4262 X 4210 km
87° INCLINATION
SPACECRAFT WEIGHT:
265 POUNDS
LAUNCH VEHICLE:
THRUST AUGMENTED
THOR AGENA-D
EXPERIMENT:
GEOMETRIC GEODESY
INVESTIGATORS:
NASA
C&GS
DOD
SAO
INTERNATIONAL
NASA SG 65-749
Rev. 10-20-66

The following individuals have primary responsibility for use of the data from particular observational techniques using either the active (GEOS) or passive (PAGEOS) satellites.

1. M. Rosenbaum, U.S. Air Force

   PC-1000 Air Force camera teams make photographic observations of flashing optical beacons on GEOS in the long arc mode for gravimetric geodesy analysis.

2. J. S. McCall, Army Corps of Engineers

   Use basic observational techniques to accomplish intercontinental, interdatum, and interisland geodetic ties and to provide a scale for the optical triangulation networks.

3. C. Lundquist, Smithsonian Astrophysical Observatory

   Analyze geodetic satellite data to obtain a representation of the gravitational potential of the Earth by a series of spherical harmonics; determination of positions of the 12 Baker-Nunn stations on a common coordinate system; determination of the relationships of the major geodetic datums.

4. J. H. Berbert, GSFC

   Comparison and correlation of radio and optical geodetic tracking systems.

5. R. Anderle, Naval Weapons Laboratory

   Use Doppler system to refine the description of the Earth's gravity field (dynamic geodesy).

6. W. M. Kaula, M. Caputo, B. Douglas, D. Lewis, University of California, Los Angeles

   Analyze camera and range and range-rate observations to determine the gravitational field of the Earth.

7. H. Plotkin, GSFC

   Obtain accurate range and angular measurements to the satellite by use of a laser.

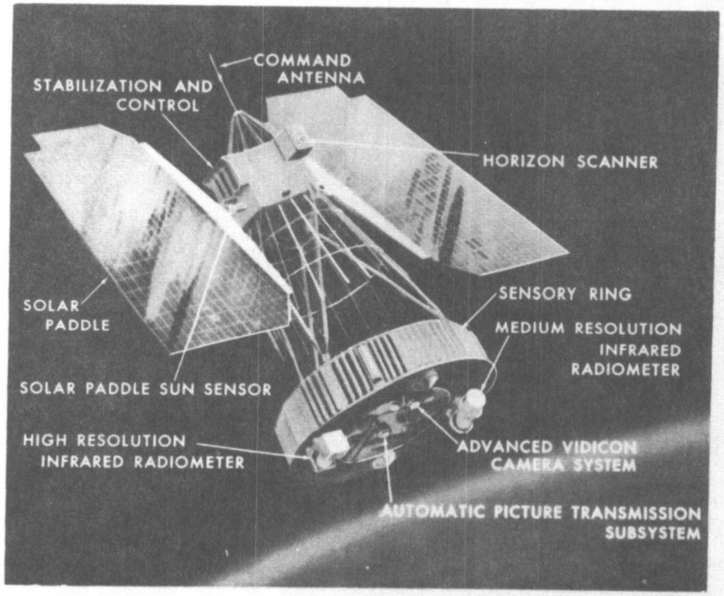
8. I. I. Mueller, S. Cushman, H. D. Preuss, Ohio S. University

Geometric-geodetic analysis of observation results using both simultaneous and orbital methods to develop a unified world datum.

9. Capt. L. W. Swanson, U.S. Coast & Geodetic Survey

Passive satellite triangulation by means of simultaneous observations of PAGEOS to derive a figure of the Earth with a minimum of hypothesis about gravity or the local vertical.

NIMBUS II



GROSS WEIGHT	418 KG
INSTRUMENT WT	88 KG
EXPERIMENTS	4
POWER	470 WATTS
STABILIZATION	ACTIVE 3 AXIS
DESIGN LIFE	SIX MONTHS
LAUNCH VEHICLE	TAT - AGENA B
ORBIT	CIRCULAR 1110 KM INCLINATION 80° RETROGRADE
STATUS	LAUNCHED MAY 15, 1966

NASA SF64-222
Rev. 11-17-66

NIMBUS

Nimbus is a three-axis, Earth-stabilized, research and developmental meteorological satellite capable of providing full Earth coverage on a daily basis by means of a nearly polar orbit having an inclination of approximately 80 degrees to the equator. The Earth's rotational movement provides the mechanism for longitudinal coverage while latitudinal coverage is obtained by the spacecraft's orbital motion. The satellite will always view the Earth at nearly local noon on the sunlit side and nearly midnight on the dark side.

The Nimbus program objective is to conduct research and development aimed at developing and exploiting space technology for meteorological research purposes. The program includes launch and operational phases for a series of meteorological satellites exhibiting evolutionary advances in operating characteristics, and carrying payloads of significant experiments for atmospheric research and operational use. The satellite consists of three major subsystems -- power, stabilization, and the sensory ring. The latter houses the advanced sensors. For this application, Nimbus serves as a meteorological observatory in space. As such, the spacecraft consists of a platform for sensor testing, a platform for subsystem testing, a platform where special atmospheric observations can be made, as well as a platform from which simultaneous measurements can be made. These measurements will be of the many parameters which are essential to the full description of the atmosphere and the understanding of it. It is also useful to take measurements simultaneously of space environmental factors (the solar environment) and the co-existing behavior of the Earth's atmosphere, therefore permitting a time correlation of the two.

Nimbus II

Nimbus II was launched on May 15, 1966. It included an Advanced Vidicon Camera System (AVCS), Automatic Picture Transmission (APT) subsystem, and the High-Resolution Infrared Radiometer (HRIR), all of which were carried aboard Nimbus I, plus a Medium-Resolution Infrared Radiometer (MRIR). Nimbus II, originally the backup for Nimbus I, incorporated a correction to the solar array drive which caused the failure of the first Nimbus spacecraft. Nimbus I was launched August 23, 1964, and ceased providing useful data on September 23, 1964.

The AVCS is a three-camera array, each camera utilizing a one-inch vidicon with an 800 TV line resolution. The system is capable of providing full global daylight cloud cover data.

The APT subsystem automatically snaps a TV picture and by a slow scan technique transmits a cloud cover picture directly to relatively inexpensive ground stations within radio range of the satellite.

The HRIR uses the 3.4 to 4.2 micron region of the infrared spectrum to provide nighttime readout of cloud cover data. This information is broadcast to specially equipped APT stations as well as to the conventional command and data acquisition stations. A resolution of almost 8 km has been achieved.

The MRIR is a five-channel radiometer that provides data concerning the emitted and reflected radiation of the Earth's surface, with a resolution of about 48 km, to study the structure and heat budget of the atmosphere:

Channel 1 - Water vapor absorption band, 6.5 to 7.0 microns.
Channel 2 - Atmospheric window; 10 to 11 microns.
Channel 3 - Stratospheric temperatures, 14 to 16 microns.
Channel 4 - Terrestrial radiation, 5 to 30 microns.
Channel 5 - Albedo, 0.2 to 4 microns.

Nimbus B

This spacecraft will be launched in 1967 into an orbit similar to Nimbus II at an altitude of approximately 1100 km. The basic spacecraft will be essentially identical to Nimbus I and Nimbus II. The experiments to be flown are described below.

1. The Image Dissector will provide a continuous daylight picture of the Earth's cloud cover.

   G. Branchflower
   Goddard Space Flight Center

2. The High Resolution Infrared Radiometer will detect the thermal radiation of the Earth and its atmosphere to produce cloud cover pictures and to measure temperatures of the surface or the cloud tops at night.

   L. Foshee
   Goddard Space Flight Center

3. The Solar UV Experiment will monitor the ultraviolet solar flux in five bands to detect time variations in relative intensity.

   D. Heath
   Goddard Space Flight Center

4. The Infrared Interferometer Spectrometer will continuously sample the spectrum of the Earth's atmospheric radiation in the 5 to 20 micron region to determine the amount of ozone and water vapor and to infer the temperature of the atmosphere.

R. Hanel
Goddard Space Flight Center

L. Chaney
University of Michigan

5. The Satellite Infrared Spectrometer will measure the Earth's spectral radiances in the carbon dioxide absorption band for inference of atmospheric temperature structure by utilizing narrow intervals within the 15 micron CO_2 band.

D. Wark/D. Hilleary
Environmental Science Services Administration

6. The Interrogation, Recording, and Location System will collect scientific data relating to the surface of the Earth and its atmosphere from fixed or free-floating platforms.

G. Hogan/J. Cressey
Goddard Space Flight Center

7. The Medium Resolution Infrared Radiometer will measure the intensity and distribution of emitted infrared and reflected radiation of the Earth and atmosphere in five selected channels (0.2 to 30 micron region).

A. McCulloch
Goddard Space Flight Center

8. The 50-watt SNAP-19 Radioisotope Thermoelectric Generator will be used to assess the operational capability of radioisotopic power for meteorological satellites and to augment the satellite's power supply.

C. Baxter
Atomic Energy Commission

Nimbus D

Following the launch of Nimbus B, it is planned to launch a fourth spacecraft, Nimbus D, in 1970. With Nimbus D it is planned to explore further the atmosphere with significant improvement in techniques developed for Nimbus B and with some new techniques in as yet unexplored regions of the electromagnetic spectrum. The experiments selected for Nimbus D are:

1. An ultrahigh frequency receiver will be used to detect sferics signals (using 600 mc, with a resolution of around 320 km) for global measurement of thunderstorm field strength both day and night.

   S. Rossby
   University of Wisconsin

2. An improved infrared interferometer spectrometer (8-40 microns) will measure the Earth's spectral radiances to provide ozone water vapor and temperature data.

   R. Hanel/B. Conrath
   Goddard Space Flight Center

3. Use the satellite transmitter and an interrogation, recording, and location system to measure atmospheric wind speed and direction and other meteorological and geophysical phenomena which may be directly sensed in the atmosphere or on the Earth's surface.

   G. Hogan
   Goddard Space Flight Center

4. A Fastie-Ebert grating spectrometer will be used to determine world-wide three-dimensional distribution of temperature and water vapor in the troposphere and the lower stratosphere.

   D. Wark/D. Hilleary
   Environmental Science Services Administration

5. A two-channel high resolution infrared radiometer (10-12 and 0.5 - 0.75 microns) to experiment with acquiring both day and night cloud cover information with an infrared system.

   A. McCulloch/I. L. Goldberg
   Goddard Space Flight Center

6. A double monochromator-type spectrophotometer with a narrow-band interference filter photometer will be used to measure the total ozone and vertical ozone distribution above 25 kilometers.

   J. Dave
   National Center for Atmospheric Research

   D. Heath
   Goddard Space Flight Center

7. A grating spectrometer will measure the cloud-top pressure altitudes and other calculable factors.

   D. Wark
   Environmental Science Services Administration

F. Saiedy
University of Maryland

8. A filter wedge spectrometer will be used to measure the water vapor content and its vertical distribution.

W. Hovis
Goddard Space Flight Center

9. An image dissector camera and line-by-line scanning system with its viewing axis pointing at the subsatellite point will be used to acquire high-resolution daytime cloud cover in a continuous pictorial strip.

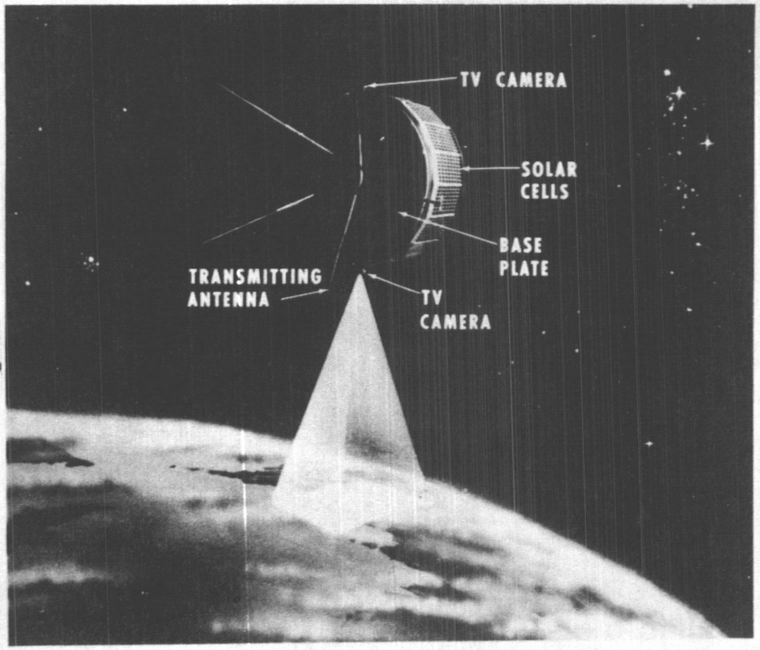
G. Branchflower
Goddard Space Flight Center

10. A selective chopper radiometer will be used to measure the Earth's emitted infrared radiation (15 micron band) for determination of the atmospheric temperature structure.

J. Houghton
University of Oxford, England

S. D. Smith
Reading University, England

TIROS



GROSS WEIGHT	138 KG
INSTRUMENT WEIGHT	27 KG
SENSORS	2 TV CAMERAS
POWER	20 WATTS
STABILIZATION	SPIN
DESIGN LIFE	6 MONTHS
LAUNCH VEHICLE	DELTA
ORBIT	APOGEE 1388 KM PERIGEE 1388 KM INCLINATION 98.7°
STATUS	FIRST LAUNCH APRIL 1, 1960 OPERATIONAL JULY 2, 1965

NASA SF64-220
Rev. 11-17-66

TIROS

The Television Infra-Red Observation Satellites (TIROS) are a series of spin-stabilized meteorological spacecraft. Weighing from 120 to 138 kilograms, they have been launched into inclined, and more recently into nearly polar, orbits to obtain television and infrared data for use by meteorologists both in research and for operational purposes. Further, these satellites have been used to advance the space technology utilized in meteorological satellites.

The success of the series has led to the extension of the objectives to include the development of an improved operational data coverage capability and the extension of the R&D capability for this type spacecraft.

Probably the greatest single contribution of the meteorological satellite program to date is the basis it has provided for the implementation of the TIROS Operational Satellite (TOS) system -- an operational system based on TIROS technology. The TOS system was implemented early in calendar year 1966. In the initial system two spacecraft types are used: One includes an Automatic Picture Transmission (APT) subsystem to provide direct local readout of cloud cover data, and the second, incorporating an Advanced Vidicon Camera System (AVCS), provides global cloud cover to be read out at Command and Data Acquisition stations. It is significant to note that both of these camera systems were developed for and successfully flown on Nimbus I and II. The basic spacecraft used in the operational system is based on the wheel configuration of TIROS and was first successfully demonstrated by TIROS IX. In the wheel configuration the spin axis is turned so as to be perpendicular to the orbital plane. Thus, as the spacecraft operates in a nearly polar orbit it sweeps out a pole-to-pole swath taking a picture, as required, when the cameras look directly down at the Earth. The Earth-oriented pictures are provided continually by the wheel-configured satellites. This is the mode of operation for the TOS series and all but the first (TIROS X) of the Operational TIROS series. TIROS X, the first Weather Bureau-funded TIROS spacecraft launched in July, 1965 to provide coverage during the hurricane season, continues to provide nearly global coverage to supplement the operational system.

Plans include the development of a spacecraft (TIROS M) to incorporate the APT, AVCS and High Resolution Infrared Radiometer (HRIR) capability into a single spacecraft. This will provide stored picture data for global use as well as local readout of cloud photographs both day and night from a single spacecraft.

The HRIR sensor is the type developed for and successfully demonstrated on Nimbus I and II. The instrument contains a scanning element which revolves the optical axis through a plane at the video line rate and depends on orbital motion to provide a complete video system.

In the present TOS program two spacecraft are required to provide daytime local and global cloud pictures.

Present plans are to convert the TOS next buy to the TIROS-M configuration. The first such operational spacecraft which will be called Improved TOS will be available for launch during CY 1969.

RESEARCH METEOROLOGICAL SOUNDING ROCKETS

The Space Applications Programs include a Research Meteorological Sounding Rocket Program aimed at exploring the meteorological structure and dynamics of the altitude region from 30 to 100 km. The several measurement techniques are aimed at determining:

The seasonal and temporal variations of the large scale circulation

The polar stratospheric and mesospheric structure

The temperature and wind structure in noctilucent clouds

The synoptic scale circulation, including stratospheric warmings and horizontal eddies

The solar influences (long term, seasonal, diurnal, and short term)

These objectives have been partially achieved. In terms particularly related to specific atmospheric phenomena, the program in the coming year will be aimed at obtaining data and analyzing it relative to:

Gravity waves and tidal effects

Turbulent energy exchange between the mesosphere and thermosphere

External energy inputs (solar ultraviolet, aurorae)

Relation of composition to the heat budget

Interactions between the neutral and charged media

A total of approximately 50 rocket flights per year are launched from sites at Wallops Island (WI), Virginia; Ft. Churchill (FC), Canada; Pt. Barrow (PB), Alaska; and Natal, Brazil (NB); with occasional test flights of instrumentation from the White Sands (WS) Missile Range, New Mexico. Nike-Apache, Nike-Cajun, and Aerobee 150 rockets have been used. The payloads consist of one or more experiments developed by scientists from universities, industry, and NASA Field Centers.

A list of experiments scheduled for launch during the coming year follows.

Investigator	Institution	Experiment	Launch Site
W. S. Smith	Goddard	Acoustic grenade	WI, FC, PB, NB
J. J. Horvath	Univ. of Mich.	Pitot-static tube	WI, FC
J. F. Bedinger	GCA Corp.	Sodium/TMA	WI
E. Hilsenrath	Goddard	Ozonesonde	WS

NAVIGATION

The objectives of the Navigation Program are to (1) develop space techniques for position fixing of mobile terrestrial and airborne craft; (2) develop traffic control techniques using space technology; and (3) develop space technology for the collection of data from moving and stationary instrumental platforms.

To develop the technology required for this program the following experimental techniques are under study:

A. Distance Measurement

The distance between the known location of a satellite in space and a moving craft can be determined by measuring the transit time from the user to the satellite and return. Either CW or pulse transmission techniques are applicable. Two such distance measurements are needed to provide a position fix. The Interrogation, Recording and Location System (IRLS) experiment on Nimbus B and D will provide position data of manned and unmanned craft.

B. Distance Rate Measurement

The time rate of change of distance between a transmitter and receiver can be measured directly by observing the doppler shift of a radio signal from its nominal frequency. The integral of the range rate taken over a specified time can be obtained by counting the number of cycles of the doppler frequency during this interval.

This technique is planned for use in the cooperative international space program between NASA and France. The FR-2/EOLE satellite will contain a highly stable oscillator in the 400 mc/s frequency band. The doppler signals will be received by transceiver equipment and relayed back to the satellite for eventual retransmission to the ground. Position computation will be done at ground computers.

C. Angle Measurement

An interferometer located on board a satellite can be used to measure the angle between the user craft and the satellite. Using a pair of mutually perpendicular interferometers, two angles and the craft's position can be determined. The angles are determined by measuring the phase difference between the two antennas of the interferometer. This technique is presently under study.

D. Hyperbolic Measurement

The signals transmitted from a pair of fixed ground navigation stations can be used by ships, aircraft and unmanned platforms to

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obtain position fixes. The Omega system of navigation operates in the VLF (10-14 kc/s) frequency range. A family of hyperbolic lines-of-position are obtained through determination of the phase difference from two stations. Continuous pulses are transmitted sequentially from each station.

An experiment on ATS-C will test this technique whereby the Omega phase difference information will be transmitted from the craft or platform to the satellite and relayed to a ground station for position data.

MANNED SPACE SCIENCE

The manned space science effort is a program of science and applications to utilize and expand the capability of man in space in fulfillment of the broad objectives of NASA. To define and develop investigations to be carried out on manned missions, close coordination with the Office of Manned Space Flight (OMSF) is maintained by the Office of Space Science and Applications (OSSA). To assist OSSA in defining, evaluating, and reviewing the scientific aspects of these investigations, a group of advisory subcommittees has been established whose members are prominent in the scientific community, NASA and government agencies.

Scientists - Astronauts

An important phase of the manned space science effort is that of Scientist - Astronaut selection and training. Since the implementation of this program in 1965, six scientists are in training as astronauts. They are presently undergoing rigorous training in jet flying, astronautics and space flight techniques. In addition, they are receiving specialized training in the scientific aspects of the Apollo missions. NASA is considering additional recruitment of qualified scientists to enter the astronaut program and start pilot training in calendar year 1966. The possibility of using scientists as passengers rather than crew members is being investigated. The advantage of using scientists of exceptional competence as non-crew members would be in utilizing their scientific talents on a full-time rather than part-time basis.

Manned Space Science Investigations

The program of manned space science investigation, which started with a few simple scientific experiments in the Mercury flights, is evolving into an increasingly sophisticated program of coordinated investigations which will required the presence of scientifically trained astronauts for its successful accomplishment. With the evolution of the Manned Space Flight Program and the greater availability of space, weight and power for experiments over long duration flights, a well planned and coordinated program for scientific investigations is required. Earth orbital, lunar orbital and lunar surface missions are being developed. These mission programs are as follows:

Gemini - The Gemini program has provided an opportunity for astronaut-conducted scientific experiments. The scientific experiments and respective flights for Gemini VIII through XII are as follows:

Gemini VIII, IX, X

Zodiacal light and airglow photography with a series of electrically controlled exposures initiated by the astronaut, using a modified 35 mm widelux camera with a rotating lens. (S001)

E. P. Ney
University of Minnesota

W. Huch
University of Minnesota

Gemini VIII, XII

Determine the effects of sub-gravity on cellular phenomena in frog eggs: (a) cell division after fertilization of the eggs under normal and under zero-G conditions (b) cell mobility (c) cell differentiation and morphogenesis. (S003)

R. S. Young
Ames Research Center

Gemini XI

Determine the synergistic effects of radiation and zero G on white blood cells and Neurospora. (S004)

M.A. Bender
Oak Ridge National Laboratory (AEC)

Gemini VIII, IX, X, XI, XII

Using a 70 mm Hasselblad camera, obtain high-quality, small scale photographs of selected parts of the Earth's surface for use in several research fields. (S005)

P. D. Lowman, Jr.
Goddard Space Flight Center

Gemini VIII, IX, X XI, XII

Use a 70 mm Hasselblad camera to obtain high-quality photographs made selectively of cloud types, fronts, etc. (S006)

K. M. Nagler
US Weather Bureau, ESSA

S. Soules
US Weather Bureau, ESSA

Gemini VIII

Spectrophotograph of high cirrus and low stratus clouds using a 35 mm spectrograph with a resolution of 20 A/mm from 7550 - 7550A. (S007)

F. Saidey
US Weather Bureau Satellite Center

Gemini VIII, XI

Study cosmic radiation using a nuclear emulsion package which will be exposed outside the spacecraft and withdrawn before reentry. (S009)

M. Shapiro
Naval Research Laboratory

C. E. Fichtel
Goddard Space Flight Center

Gemini VIII, IX, X, XII

Collect micrometeorite samples using a collection approach with isolated compartments to study the physical and chemical nature of interplanetary dust in its primary form. (Package on Agena) (S010)

C. L. Hemenway
Dudley Observatory

Gemini IX, XI, XII

Use a camera with f/0.95 lens and a split filter to photograph the airglow (OH and Na 5893) so that nightside data are obtained for all parts of the Earth. The astronaut will orient the spacecraft and control the attitude during the exposure time. (S011)

M. J. Koomen
Naval Research Laboratory

D. M. Packer
Naval Research Laboratory

Gemini IX, X, XII

Collect micrometeorites to study the physical and chemical nature of interplanetary dust; and test for the presence of microorganisms. The collection apparatus attached on the outside of the Gemini capsule will be uncovered, exposed and later recovered. (S012)

C. L. Hemenway
Dudley Observatory

J. Hotchin
Dudley Observatory

Gemini X, XI, XII

Test the techniques for UV photography under vacuum conditions. Obtain spectra of O&B stars and some of the planets, and obtain a UV survey of as much of the galactic plane as possible. The astronaut will position a 35 mm Schmidt or similar camera, with a grating device to provide a dispersion of 200A/mm, and will guide it manually, employing extra-vehicular activity. (S013)

K. G. Henize
Northwestern University

Gemini X, XI

Investigate the ionospheric wake of an orbiting spacecraft (i.e., measure charged particle densities and temperatures within the wake relative to those of the ambient plasma) and evaluate the possibility of using this ionospheric wake as guidance mechanism to facilitate rendezvous of two orbiting spacecraft. (S026)

D. B. Medved
Electio Optical Systems

Gemini XI, XII

A Maurer camera, f/0.95 lens, and fast black-and-white film, will be used to photograph the L_4 and L_5 regions (60° behind and 60° ahead of the Moon's path) to determine the existence of dust or particulate matter at these points. (S029)

E. C. Morris
U. S. Geological Survey

Gemini XI

A D-15 image orthicon will be used to observe astronomical phenomena; photographic recordings of the output will be studied using microdensitometer techniques to derive brightness values for the observed objects (the Milky Way, the airglow layer viewed in profile, the zodiacal light, the Gegenschein and the Lagrangian libration points). (S030)

C. Hemenway
Dudley Observatory

E. Ney
University of Minnesota

Gemini XII

Demonstrate the feasibility of measuring winds at ionospheric altitudes during the day time by satellite observations of chemical releases above the airglow and scattering layers, and measure the wind vector from 90 to 200 km at low latitudes and in the electrojet. (S051)

J. E. Blamont
Centres National De la Recherche Scientiques, CNES

The results of the Gemini scientific experiments to date are as follows:

			Gemini Flight Number									
			III	IV	V	VI	VII	VIII	IX	X	XI	XII
	S001	Zodiacal Light Photography			+			O	+	/		
	S002	Sea Urchin Egg Growth	O									
	S003	Frog Egg Growth						/				.
	S004	Radiation and Zero G on Blood; <u>Neurospora</u> added on GT-XI	+								+	
****	S005	Synoptic Terrain Photos	/	+	+	+	+	/	+	+	+	.
****	S006	Synoptic Weather Photos		+	+	+	+	/	+	+	+	.
	S007	Cloud Top Spectrometry			/			O				
	S008	Visual Acuity			/		+					
	S009	Nuclear Emulsions						O			+	
	S010	Agena Micrometeorite								*		
		Collection						/	/	/		.
	S011	Airglow Horizon Photography							+		+	.
	S012	Gemini Micrometeorite Collection							+	O		.
	S013	UV Astronomical Camera								/	+	.
	S026	Ion Wake Measurement								/	+	
	S029	Libration Regions/Photos									O**	.
	S030	Image Orthicon/Photos									****	
	S051	Sodium Vapor Clouds										.

LEGEND

- . Experiment scheduled - too early for results
- + Experiment successful
- / Experiment partially successful
- 0 Experiment failure for various reasons
- * S010 recovered from Agena VIII
- ** Libration regions unavailable at time of this flight
- *** Experiment carried out according to plan, results unknown at this time.
- **** 1500 usable color photos obtained.

Apollo - The manned science in the Apollo-Earth Orbital program is a continuation of the manned science in the Gemini program. In certain areas Gemini experiments will be expanded and improved to take advantage of the increased weight, space, and power available. The following is a list of experiments and respective flight assignments which have been approved for the Earth-Orbital Apollo flights.

Apollo SA 204, 205, 207

Using similar techniques and equipments as in Gemini, obtain high-quality, small scale photographs of selected parts of the Earth's surface for use in several research fields. (S005)

P. D. Lowman, Jr.
Goddard Space Flight Center

Apollo SA 204, 205, 207

Use a 70 mm Hasselblad camera to obtain high quality photographs made selectively of cloud types, fronts, etc. (S006)

K. M. Nagler
US Weather Bureau

S. Soules
US Weather Bureau

Apollo SA 205

Determine whether or not prolonged exposure of isolated human cells to zero gravity results in morphologic, functional, biochemical, or genetic abnormalities in such cells. (S015)

P. O'B. Montgomery
Dallas County Hospital District

Apollo SA 205 Continued

R. C. Reynolds
Dallas County Hospital District

J. E. Cook
Dallas County Hospital District

Apollo SA 205

Study the energy spectrum, flux and east-west asymmetry of geo-magnetically trapped radiation in the region of the South Atlantic Anomaly. (S016)

H. H. Heckman
University of California, Berkeley

Apollo SA 205

X-ray astronomy program. Instrumentation consists of a basic group of detectors, beryllium window proportional counters, arranged in such a way that their fields of view overlap and scan a 2° by 2° area of the sky. (S017)

R. Giacconi
American Science and Engineering

B. B. Rossi
Massachusetts Institute of Technology

H. Gursky
American Science and Engineering

J. R. Waters
American Science and Engineering

Apollo SA 205

Collect small micrometeorites and measure directly fluxes of larger micrometeorite particles at satellite altitudes. Secondary purpose is to carry out biological exposure and collection experiments. (S018)

C. L. Hemenway
Dudley Observatory

Apollo SA 207

Direct photographs of the wavelength region between 1300A and 3000A will provide approximate strengths of stellar absorption and emission lines, UV stellar spectral energy distributions, UV stellar luminosities positions, sizes, and densities of light-absorbing interstellar dust clouds, positions and sizes on new O-associations, etc. A two-mirror Baker Schmidt camera will be used. (S019)

K. G. Henize
Northwestern University

Apollo SA 207

Photography of the extreme UV and X-ray (XUV) spectrum of the Sun (1000A to 10A). A grazing-incidence spectrograph at 2° grazing angle equipped with a thin unbacked aluminum filter will be used. (S020)

R. Tousey
Naval Research Laboratory

J. D. Purcell
Naval Research Laboratory

W. E. Austin
Naval Research Laboratory

Apollo SA 209

A camera and grating system is mounted by the astronaut in the spacecraft window. Spacecraft is then oriented to view the airglow layer. Pitch attitude is closely controlled (± 1°) for each exposure. A f/0.95 lens is used and exposure required approximately two minutes. Measurements of the nature and structure of the airglow provide knowledge of the composition, temperature, ionization, and structure of the atmosphere difficult to obtain by other methods. Repeat of Gemini experiment, but experiment will be updated using results of Gemini flights. (S021)

R. Tousey
Naval Research Laboratory

M. J. Koomen
Naval Research Laboratory

D. M. Packer
Naval Research Laboratory

Apollo (Approved experiments but awaiting flight assignment)

Use nuclear emulsions to detect and identify particles in the entire energy spectrum of heavy ($Z > 3$) primary cosmic rays. (S022)

C. E. Fichtel
Goddard Space Flight Center

A detailed study of the characteristics of the low energy (between 50 and 300 Mev/nucleon), high charge nuclei ($Z > 20$) in the primary cosmic radiation. (S023)

C. J. Waddington
University of Minnesota

P. Freier
University of Minnesota

Survey a portion of the sky for X-ray sources of low flux (0.01 cm^{-2} sec^{-1}) using newly developed instrumentation consisting of a tray of ten 2-mill beryllium-window xenon-filled proportional counters surrounded on five sides by a plastic charged-particle veto counter. Honeycomb collimators will be mounted in front of the beryllium windows. (S027)

W. L. Kraushaar
University of Wisconsin

Apollo SA 204

Dim sky phenomena will be objects for photographic investigation, using 16 mm camera and/or still photography, including "Preliminary Twilight Studies" and twilight bands. (S028)

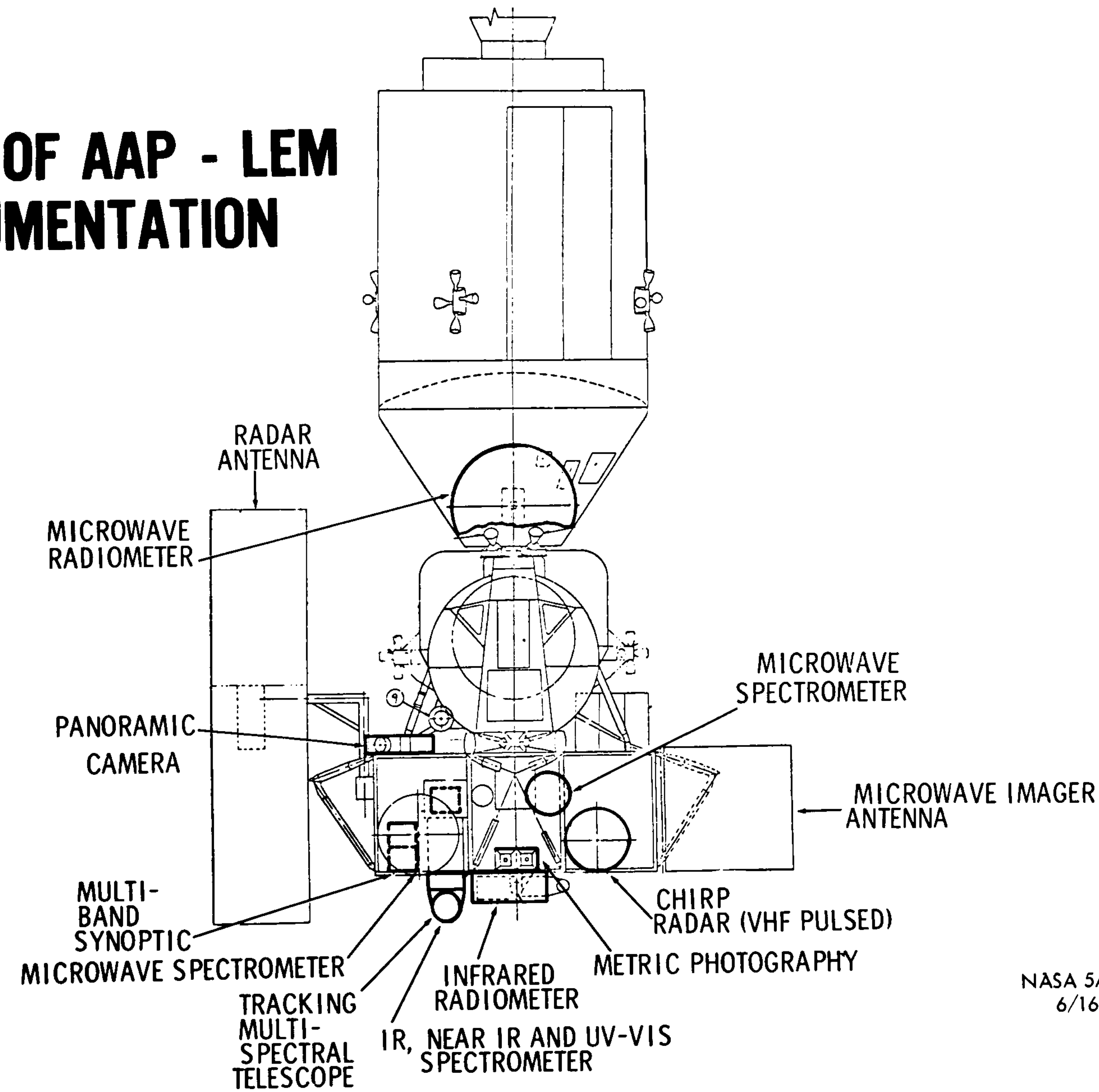
L. Dunkleman
Goddard Space Flight Center

Apollo SA 204

Demonstrate the feasibility of measuring winds at ionospheric altitudes during the day time by satellite observations of chemical releases above the air glow and scattering layers, and measure the wind vector from 90 to 200 km at low latitudes and in the electrojet. (S051)

J. E. Blamont
Centres National De la Recherche Scientiques, CNES

CONCEPT OF AAP - LEM INSTRUMENTATION



NASA 5A66-15671
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In addition to these experiments which have been approved for the early Apollo Earth Orbital flights, development of an airlock will allow experiments which require exposure to the outside environment to be stored in canisters within the Command Module and raised to a position outside the spacecraft for operation. Use of this airlock will eliminate the need for extra-vehicular activity by the astronaut in performing experiments such as trapped radiation studies, micrometeorite collection, UV stellar photography, and X-UV solar photography.

Apollo Applications Program

Earth orbital flights in an Apollo Applications Program (AAP) could provide the opportunity to accommodate experiments of greater weight and/or complexity than previously possible by using slightly modified Apollo equipment. For example, by stripping the lunar components from the Lunar Excursion Module (LEM) and flying it in Earth orbit, added weight and space for scientific and applications experiments would become available.

The scientific mission of Applications-A (AAP-A) consists of fourteen complementary and compatible experiments which utilize sensors that are generally Earth-oriented. The objectives of this experiment package are to:

1. Conduct meteorological experiments in order to evaluate concurrently a number of mutually supporting instruments, establish their flight worthiness, and to examine man's capability to control and/or modify the experiments.

2. Conduct world-wide Earth resources survey experiments to establish their value in the discovery, inventory, development, and conservation of natural and cultural resources.

3. Determine the usefulness of the millimeter region for communications.

4. Employ the unique capabilities of the astronaut.

Summaries of the fourteen experiments are given below:

1. The image orthicon TV camera will view the Earth-cloud scene from 200 mile altitude orbit during both day and night, to demonstrate the value of cloud cover imaging in both the day and night portions of the Earth, and to determine the effect of the night-glow background on cloud cover imaging under "moonless" or "no-moon" conditions.

J. C. Moody
Goddard Space Flight Center

H. Ostrow
Goddard Space Flight Center

2. A dielectric tape camera system will provide high-quality, high-resolution photographs of the Earth's cloud cover, to demonstrate the value of high-resolution cloud cover television for meteorological analysis and prediction; will facilitate the study of phenomena related to the formation, size (extent), and path (movement) of hurricanes, tornadoes, and thunderstorms; to study the application of high-resolution television as a support for the related disciplines of agriculture, geology, and cartography; to gain experience which will assess the usefulness of the tape camera as a general-purpose high-resolution exploratory device for future lunar or planetary missions; and to gather data relating to the photometric behavior of the Earth and its cloud cover as a function of Earth/Sun orientation.

J. Arlauskas
Goddard Space Flight Center

H. Ostrow
Goddard Space Flight Center

3. The millimeter wave propagation characteristics of the atmosphere will be observed by measuring the amplitude and phase of signals at 16 and 35 GHz which will be transmitted from the spacecraft through the Earth's atmosphere and to ground stations for recording. The measured data will yield information about atmospheric dispersion, refraction, and flat and selective frequency fading as a function of elevation angle and various meteorological conditions.

G. B. Nichols
Goddard Space Flight Center

A. Hedrich
Goddard Space Flight Center

4. Six cameras are to be commonly boresighted and synchronized to provide multispectral and synoptic-scale photographic data for use in measuring local and regional spectral reflectance distributions over selected areas of the Earth's surface; spectral intensity of reflected radiation from the Earth's surface in or near the visible spectrum (0.3 to 1.1 micron); and object sizes, shapes, textures, and configurations over large areas of the Earth's surface within resolution of the camera system (30 meters).

D. G. Orr
U. S. Army Corps of Engineers

Numerous other individuals from
the disciplines of agriculture,
geology, geography, cartography
and oceanography.

5. A 35-channel infrared spectrometer (modified Ebert design) will be used to measure the solar radiation reflected from the Earth's surface and the top of the cloud layers and to obtain data in selected spectral bands of the CO_2 radiance in the atmosphere (4.3 microns and 34 other bands between 3.6 and 5.0 microns), to determine the vertical temperature profile of the atmosphere from the surface to the 1-millibar pressure level.

J. H. Shaw
Ohio State University

L. Kaplan
Jet Propulsion Laboratory

P. Schaper
Jet Propulsion Laboratory

6. A near infrared filter wedge spectrometer will be used to measure reflected and thermally emitted infrared radiation from Earth in the 1.5 to 6 micron region. This experiment will be an extension of the measurements that have been carried out by radiometers on TIROS and Nimbus meteorological satellites.

W. A. Hovis
Goddard Space Flight Center

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7. Integrated passive microwave experiment consisting of three parts:

I. Five Dicke-type radiometers (at frequencies of 19.0, 23.5 and 32.4 Gc/s) will be used to measure and map the thermal microwave emission from the terrestrial surface and atmosphere near the 1.35 cm water vapor resonance, to provide data about the atmospheric water vapor abundance and distribution in altitude, the integrated liquid water content of the atmosphere, the surface brightness temperature, and the sea state.

D. H. Staelin
Massachusetts Institute of Technology

A. Barrett
Massachusetts Institute of Technology

W. B. Lenoir
Massachusetts Institute of Technology

F. T. Barath
Jet Propulsion Laboratory

P. Thaddeus
Institute for Space Studies, Goddard Space Flight Center

II. A 5 mm five-channel Dicke radiometer will measure the brightness temperatures as a function of geographic latitude and longitude, to check the theoretical predictions for the brightness temperature with a given temperature profile, and to check the validity of the data inversion methods leading to the temperature profile.

W. B. Lenoir
Massachusetts Institute of Technology

A. Barrett
Massachusetts Institute of Technology

D. Staelin
Massachusetts Institute of Technology

F. Barath
Jet Propulsion Laboratory

P. Thaddeus
Institute for Space Studies, Goddard Space Flight Center

III. Using a radiometer consisting of a microwave receiver and a phased array antenna, the brightness temperature of the Earth will be measured at a frequency of 19.35 Gc/s (1.55 cm wavelength) for angles of observation with respect to the zenith of from 0 to 50°. The objective is to make the first global study of the Earth's surface and lower atmosphere at long wavelengths, and to evaluate the role that microwave radiometers can play as scientific companions to sensors in other spectral regions for work on meteorological satellites.

P. Thaddeus
Institute for Space Studies, Goddard Space Flight Center

A. Barrett
Massachusetts Institute of Technology

W. Lenoir
Massachusetts Institute of Technology

D. Staelin
Massachusetts Institute of Technology

F. T. Barath
Jet Propulsion Laboratory

8. Measure the Stokes parameters of the radiation emerging in different directions from the top of the atmosphere in the visible region of the spectrum. The data will be used to study the effects of surface reflectance on the emergent radiation, to determine the vertical distribution of atmospheric aerosols, and to study the contrasting transmission properties of the atmosphere. A photoelectric polarimeter with four narrow spectral regions (100A) centered at 3600, 4200, 5000, and 5800A will be used.

Z. Sekera
University of California at Los Angeles

T. A. Hariharan
University of California at Los Angeles

U. R. Rao
University of California at Los Angeles

9. Star tracking telescopes and gyroscopes will be used to measure the refraction of light from occulting stars as a means of determining atmospheric structure. The purpose is to test and verify the new technique and theory, and to supply information on background radiance near the horizon and starlight attenuation in the atmosphere, to permit optimization of star tracker design.

F. W. Fischbach
University of Michigan

M. E. Graves
University of Michigan

D. E. Haddock
University of Michigan

J. Kuipers
University of Michigan

R. G. Roble
University of Michigan

10. A low noise UHF receiver (3 db or less) and associated antenna system (610 Mc) and data-processing equipment will measure the peak amplitude and envelope characteristics of the UHF emissions from the cumulus clouds. These data will be compared with the astronauts reports of cloud presence, form distribution, and percentage cover, and with photographs taken by the astronaut and on-board TV equipment.

S. A. Rossby
University of Wisconsin

D. F. Nelson
University of Wisconsin

H. W. Haas
New Mexico State University

11. A Michelson-type interferometer spectrometer having a spectral range from 5 to 20 microns will measure the spectral specific intensity from which information can be derived about the atmospheric structure and the surface temperature, pressure and composition.

R. A. Hanel
Goddard Space Flight Center

B. Conrath
Goddard Space Flight Center

V. Kunde
Goddard Space Flight Center

B. Schlachman
Goddard Space Flight Center

12. An eight-channel Fastie-Ebert spectrometer will be used to determine the three-dimensional temperature fields of the atmosphere, sensing spectral radiances at 669, 677.5, 692, 699, 707-717, 750 and 899 wave numbers.

D. Q. Wark
National Environmental Satellite Center, Environmental Science Services Administration

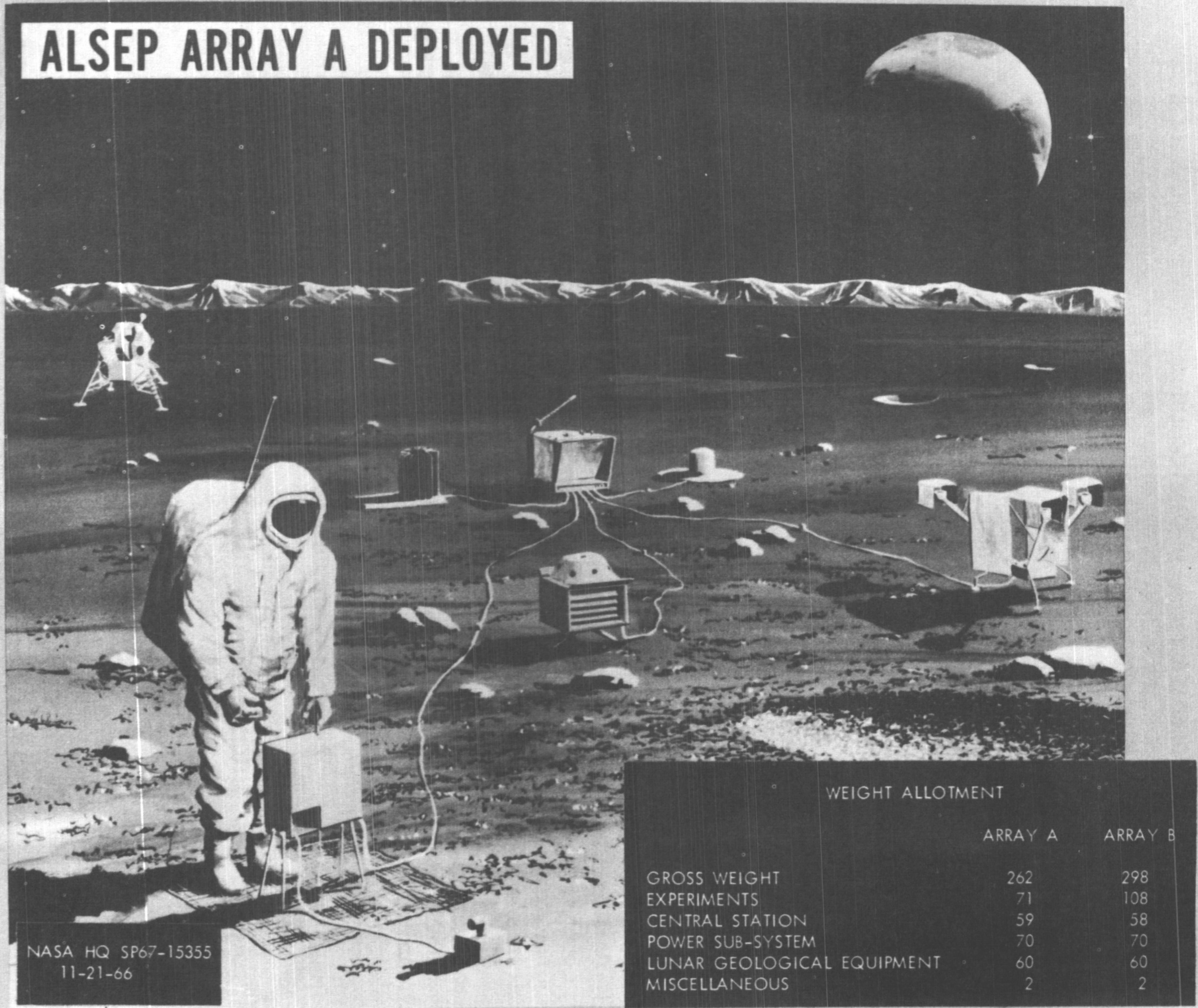
D. T. Hilleary
National Environmental Satellite Center, Environmental Science Services Administration

13. Obtain high quality maps of the Earth's surface and atmosphere combination from a three-channel radiometer and associated equipment on board the spacecraft. Data from the 6300-6500A region will be indicative of the albedo and its polarized components. The 7900-8100A region data will be used to gain information relative to the vegetative coverage of the Earth's surface, while data from the 10-11 micron region will be used to map clouds, estimate their height and give information on surface thermal properties.

D. G. Rea
University of California, Berkeley

K. Coulson
University of California, Davis

R. Colwell
University of California, Berkeley


ALSEP ARRAY A DEPLOYED
NASA HQ SP67-15355
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WEIGHT ALLOTMENT
ARRAY A ARRAY B
GROSS WEIGHT 262 298
EXPERIMENTS 71 108
CENTRAL STATION 59 58
POWER SUB-SYSTEM 70 70
LUNAR GEOLOGICAL EQUIPMENT 60 60
MISCELLANEOUS 2 2

14. Measure the emission from carbon dioxide in six channels in the 15-micron band to arrive at the atmospheric temperature structure from the ground (or highest cloud top) to 50 km altitude, using a selective chopper radiometer.

J. T. Houghton
Oxford University

S. D. Smith
Reading University

A significant part of the manned space science effort consists of scientific exploration of lunar and planetary bodies. Most of the experiments during the early Apollo lunar mission are of the type which must be left on the Moon and continue to function after the astronauts have returned to Earth. To accomplish this task, the concept of an Apollo Lunar Surface Experiments Package has been developed.

Apollo Lunar Surface Experiments Package (ALSEP)

ALSEP is part of the total Apollo science program to obtain first order measurements of the physical properties of the Moon. The purpose of the total program is to obtain a better understanding of the structure and processes of the lunar interior; the composition and structure of the surface of the Moon and the processes modifying the surface; and the history or evolutionary sequence of events by which the Moon arrived at its present configuration. ALSEP is designed to obtain scientific data and telemeter it to the Earth for a period of one year. The complete ALSEP system consists of eight experiments. Arrays of five to six of these experiments will be carried on each Apollo flight.

Following is the currently approved list of ALSEP experiments:

1. Passive Seismometer - Record moonquakes, meteoroid impacts, lunar tides, and free oscillations.

G. V. Latham
Lamont Geological Observatory

F. Press
Massachusetts Institute of Technology

G. H. Sutton
University of Hawaii

M. Ewing
Lamont Geological Observatory

2. Lunar Surface Magnetometer - Measure the equatorial surface field due to magnetic flux captured from the solar wind; and electromagnetic diffusivity of the Moon.

C. P. Sonett
Ames Research Center

J. Modisette
Manned Spacecraft Center

3. Solar Wind Spectrometer - Measure the interaction of the solar wind with the Moon.

C. W. Snyder
Jet Propulsion Laboratory

M. M. Neugebauer
Jet Propulsion Laboratory

D. Clay
Jet Propulsion Laboratory

4. Suprathermal Ion Detector - Deduce the constituents of the lunar atmosphere.

J. W. Freeman, Jr.
Rice University

F. C. Michel
Manned Spacecraft Center

5. Lunar Surface Cold Cathode Gauge - Determine pressure of lunar atmosphere.

F. S. Johnson
Graduate Research Center of the Southwest

D. E. Evans
Manned Spacecraft Center

6. Lunar Surface Active Seismometer - Determine elastic properties of lunar surface and interior to a depth of about 500 feet.

R. L. Kovach
Stanford University

J. S. Watkins
U. S. Geological Survey

7. Lunar Surface Heat Flow Experiment - Measure steady state net heat flux of Moon's interior; and deduce sources of heat.

M. Langseth
Lamont Geological Observatory

S. P. Clark, Jr.
Yale University

M. G. Simmons
Massachusetts Institute of Technology

8. Charged Particle Lunar Environment - Measure charged particles in the magnetosphere and measure solar wind in interplanetary space.

B. J. O'Brien
Rice University

In addition to emplacing ALSEP, the astronaut is expected to carry out a Field Geological Experiment to determine the composition, structure and thickness of the surficial layer of fragmental material believed to cover most areas of the Moon and the lithologic features of the underlying materials. The investigators for this experiment are:

E. M. Shoemaker
U. S. Geological Survey

E. N. Goddard
University of Michigan

J. H. Mackin
University of Texas

H. H. Schmitt
Manned Spacecraft Center

A. C. Waters
University of California, Santa Barbara

T. Foss
Manned Spacecraft Center

J. M'Gonigle
U. S. Geological Survey

Priority in the Apollo Program has been given to the analysis of lunar samples in order to obtain information on the chemical and physical properties of the surface materials.

Analysis of the samples will be performed on the Earth rather than on the lunar surface. A Lunar Receiving Laboratory, now under construction at the Manned Spacecraft Center near Houston, will contain quarantine facilities and scientific instruments to detect and identify viable organisms, measure the short-lived radionuclides and occluded gas content, and carry out preliminary examinations of the samples. As soon as the quarantine period is over and these preliminary analyses are completed the samples will be transferred to scientists throughout the country for analysis in their own laboratories.

Apollo Telescope Mount

The Apollo Telescope Mount (ATM) is being developed in the Apollo Applications Program as a space vehicle to be used with man to perform high-resolution studies of solar phenomena. The ATM will consist of a structural rack; subsystems, such as the stabilization and power; and the selected experiments. The ATM will then be mounted in place of the descent stage on a modified Lunar Excursion Module. The operational configuration has not yet been decided. It may be free, or fixed to the Command and Service Module (CSM), or tethered to the CSM. A three-axis stabilization and control system using control-moment gyros plus a vernier gimbal arrangement will maintain spacecraft orientation to within ± 2.5 arc seconds of any point within a 40 arc-minute square centered on the solar disc. Data from the ATM mission will be obtained primarily by photographic film recovered by an astronaut through extravehicular activity. However, a telemetry system will be provided with a high transmission rate and storage capacity for data acquired from at least one prime experiment (Harvard College Observatory) and for housekeeping data from the other experiments.

The ATM will be placed in the Apollo orbit of 200 nautical miles inclined 28.5 degrees to the equator. Launch of the ATM will be from the Eastern Test Range aboard either a Saturn 1B or Saturn V vehicle. First launch is planned for late 1968.

Instruments currently under development for ATM include:

1. Normal-incident spectrometer-spectroheliometer (300-1400A and 1450-2250A) for studies of the fine structure and spectra of active regions on the solar disc. (S055)

    L. Goldberg, E. M. Reeves, W. H. Parkinson
    Harvard College Observatory

2. White light coronagraph to measure the brightness, form, and polarization of the corona from 1.5 to 6 solar radii. (S052)

    G. Newkirk, J. A. Eddy
    High Altitude Observatory

3. Coronal spectroheliograph-spectrograph for the study of the upper chromosphere and corona, and spectra across the limb (170-3000A). (S053)

    J. D. Purcell, R. Tousey
    Naval Research Laboratory

4. Spectrographic X-ray telescope for the study of solar flare emissions in the soft X-ray wavelengths (2-8A). (S054)

R. Giacconi, W. P. Reidy, G. Vaiana, O. P. Manley
American Science and Engineering

B. B. Rossi, S. Olbert
Massachusetts Institute of Technology

5. High-resolution X-ray telescope to obtain time histories of the dynamics of the solar atmosphere (2-20A and 44-60A). (S056)

J. E. Milligan, W. A. White, J. Underwood
Goddard Space Flight Center

LAUNCH VEHICLE AND PROPULSION PROGRAM

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SATELLITE AND SPACE PROBE VEHICLES

The objective of the Launch Vehicle and Propulsion Programs is to provide vehicles with the capability to perform reliably and economically in the unmanned orbital, lunar, planetary, and interplanetary missions. Satellite and space probe vehicles available in this program are the Scout, Delta, Thor Agena, Atlas Agena, and Atlas Centaur.

A description of each launch vehicle, including its capabilities, is provided in the following pages.

SCOUT

● STAGES

1ST STAGE - SOLID (ALGOL)

2ND STAGE - SOLID (CASTOR)

3RD STAGE - SOLID (ANTARES)

4TH STAGE - SOLID (ALTAIR)

● MISSION CAPABILITY

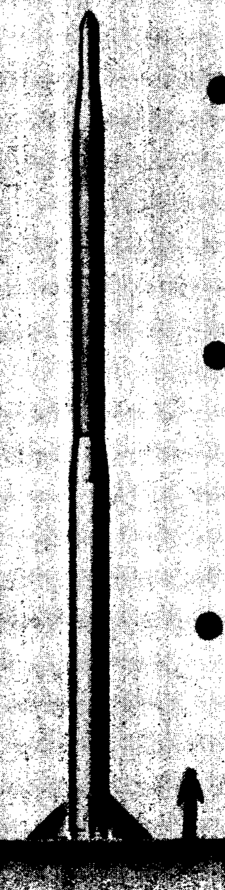
300 N. MI. ORBIT-300 LBS. AT 38° INC.

● USE

ORBIT

HIGH ALTITUDE PROBE

RE-ENTRY



● INITIATED

LATE 1958

● 1ST LAUNCHING

R & D
JULY 1960

OPERATIONAL
MAR. 1962

● LAUNCH RATE CAPABILITY

WALLOPS ISL. - 2/MO.

WTR - 2/MO.

● LAUNCH SITES

WALLOPS IS. - (2)

WTR - (1)

NASA S63-300
REV. 12/8/65

SCOUT

Description: The Scout is the smallest of the launch vehicle family. All of its four stages use solid propellants. Because of its relative simplicity, the Scout can be launched from comparatively inexpensive installations. It is a low-cost vehicle which can be used for a large variety of scientific payloads such as high-altitude probes, reentry experiments and Earth-orbiting satellites. Its guidance and control system incorporates a digital programmer and 3-axis stabilization for all except the spin-stabilized fourth stage. Ling-Temco-Vought, Dallas, Texas, is the vehicle prime contractor. The motors are obtained from Aerojet, Sacramento, California; Thiokol, Huntsville, Alabama; Hercules, Inc., Cumberland, Maryland; and United Technology Center, Sunnyvale, California.

Mission Capability: The present Scout is capable of placing 300 pounds in a 300 n.m. easterly orbit.

Schedule: Starting with the first flight on July 1, 1960, eight developmental and forty operational vehicles have been flown to date. A well integrated Scout program has been established between NASA and DOD. Sixty-four vehicles will have been procured through CY 1966 to fulfill NASA, AEC, and DOD requirements. In addition, a fully integrated logistic support system for the two Scout launch sites (Wallops Island and WTR) has been established by NASA with joint funding.

239-359 O - 66 - 12

DELTA

Description: The Delta is a three-stage vehicle. The first stage is a production Thor space launch booster. The second stage is a modified version of the Vanguard second stage, with an increased tank diameter to provide additional propellant capacity. A radio guidance system (BTL) is installed in the second stage to provide velocity and attitude control. This includes a coast-phase attitude control, which affords much higher orbits with Delta since a prescribed vehicle attitude can be maintained up to 2000 seconds after second-stage burnout. An FW-4 solid propellant rocket motor is used as a Delta third stage. Prior to ignition, this stage is spun up to approximately 150 RPM to obtain spin stability after separation, since neither guidance nor auto-pilot is carried in the third stage.

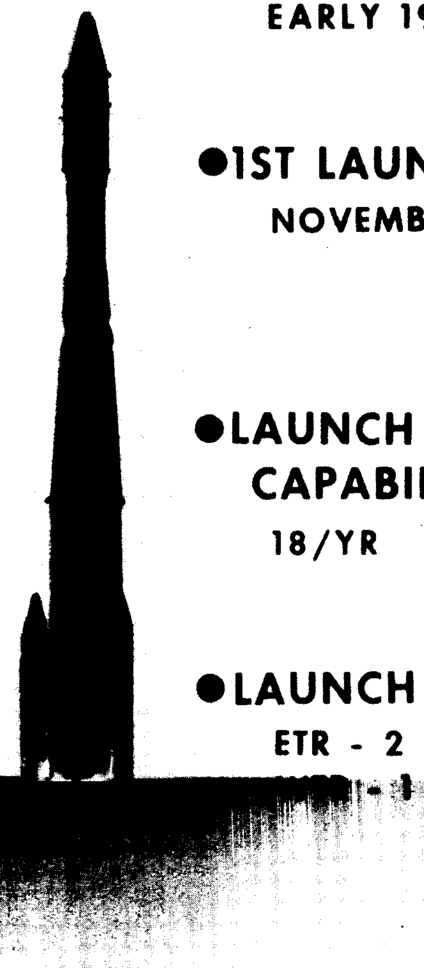
Mission Capability: The vehicle combination is capable of placing 900 pounds into a 300 n.m. circular orbit and of placing 150 pounds to escape in a thrust-augmented configuration.

Schedule: The first Delta flight was made in 1960. Delta has been successful in 37 out of 40 launch attempts through October 1966.

Additional vehicles have been ordered for use with scientific, meteorological and active communication satellite programs. These launches will continue well into calendar year 1967, and perhaps beyond, at a rate of eight to ten per year.

IMPROVED DELTA

- **STAGES**
  - STRAP-ON ROCKETS (3) SOLIDS
  - 1ST LIQUID LOX/RP (THOR)
  - 2ND STAGE-UDMH/IRFNA
  - 3RD STAGE-SOLID (FW-4)
- **MISSION CAPABILITY**
  - 300 N. MI. ORBIT - 1,400 LBS.
  - ESCAPE - 210 LBS.
- **USE**
  - COMMUNICATION SATELLITES
  - METEOROLOGY SATELLITES
  - GEODETIC SATELLITES
  - INTERNATIONAL SATELLITES



- **INITIATED**
  - EARLY 1964
- **1ST LAUNCHING**
  - NOVEMBER, 1965
- **LAUNCH RATE CAPABILITY**
  - 18/YR
- **LAUNCH PADS**
  - ETR - 2

NASA S63-700
Rev. 11-17-64

IMPROVED DELTA

Description: The Improved Delta differs from the previous Delta in that the second stage tank diameter has been increased to provide additional propellant capacity (i.e., 54 inch diameter), and the larger diameter Nimbus fairing (i.e., 60 inch diameter) has been adopted for Delta use to provide additional payload volume. The improved second stage is flown with or without first stage thrust augmentation and the FW-4 third stage.

Mission Capability: The vehicle combination is capable of placing 1400 pounds into a 300 n.m. circular orbit, and of placing 210 pounds to escape in the thrust-augmented configuration.

Schedule: The Improved Delta became operational in 1965 with the launching of GEOS A (Explorer XXIX) in November and the Pioneer VI in December.

Through November of Calendar Year 1966, three meteorological satellites were launched for the Weather Bureau, and a communications satellite for the Comsat Corporation. Along with this support, the Improved Delta was used to launch IMP D (Explorer XXXIII) and Pioneer VII. In addition, a Biosatellite spacecraft is planned to be launched before the end of Calendar Year 1966.

Continued and extensive use of the Delta is planned during Calendar Year 1967 and subsequent years in support of NASA, the Weather Bureau, and the Comsat Corporation launch requirements.

THRUST AUGMENTED DELTA (TAD)

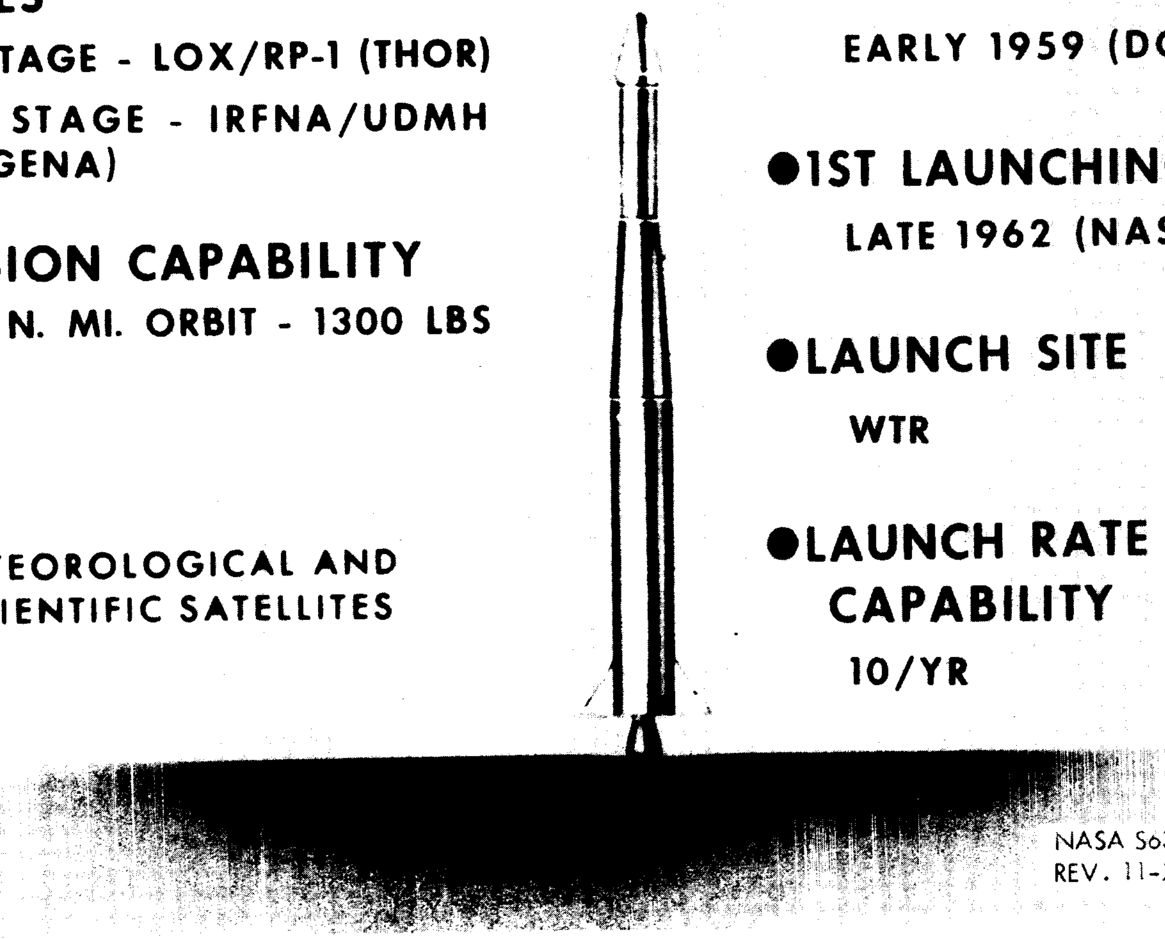
Description: The Thrust Augmented Delta is a three-and-one-half stage vehicle which differs from the Delta in that it utilizes the USAF-developed, improved Thor booster as a first stage. The improved Thor (SLV-2A) employs three THIOKOL XM-33-#2 solid propellant rocket motors mounted around the base of the Thor booster, increasing the lift-off thrust from 170,000 pounds to 330,000 pounds. The solid motors are expended at approximately 40 seconds and are separated from the booster at an appropriate time thereafter. The upper stages are not changed from the standard Delta.

Mission Capability: This vehicle combination is capable of placing 1,200 pounds into a 300 n.m. circular orbit, and of placing 210 pounds to escape.

Schedule: The Thrust Augmented Delta was first launched successfully on Delta No. 26, which placed SYNCOM-C into synchronous transfer orbit on August 17, 1964.

THOR AGENA

- **STAGES**
  - 1ST STAGE - LOX/RP-1 (THOR)
  - 2ND STAGE - IRFNA/UDMH (AGENA)
- **MISSION CAPABILITY**
  - 300 N. MI. ORBIT - 1300 LBS
- **USE**
  - METEOROLOGICAL AND SCIENTIFIC SATELLITES



- **INITIATED**
  - EARLY 1959 (DOD)
- **1ST LAUNCHING**
  - LATE 1962 (NASA)
- **LAUNCH SITE**
  - WTR
- **LAUNCH RATE CAPABILITY**
  - 10/YR

NASA S63-701
REV. 11-21-66

THOR AGENA

Description: The Thor Agena is a two-stage rocket consisting of a Thor first stage using liquid oxygen and RP-1 propellants and an Agena second stage using UDMH and IRFNA as the propellants. The vehicle is eight feet in diameter and weighs 125,000 pounds, booster thrust is 170,000 pounds and the Agena second stage thrust is 16,000 pounds.

Mission Capability: This vehicle is capable of launching a payload of 1,300 pounds into a 300 n.m. circular polar orbit. There is no Thor Agena capability from the ETR at present.

Schedule: The ISIS-X mission which was a combination of Alouette II and Explorer XXXI was launched in November, 1965 and was the last Thor Agena scheduled by NASA. Currently planned Agena missions require either the TAT Agena or Atlas Agena vehicle combination. Four Thor Agena launches have been completed to date, commencing with Alouette I in 1962.

THRUST AUGMENTED THOR-AGENA

- **STAGES**

  STRAP ON ROCKETS
  (3) SOLIDS

  1ST STAGE - LOX/RP-1
  (THOR)

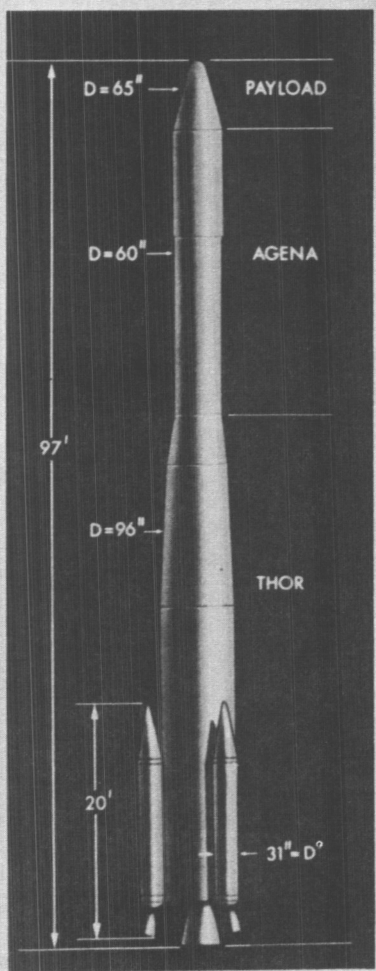
  2ND STAGE - IRFNA/UDMH
  (AGENA)

- **MISSION CAPABILITY**

  1800 LBS. AT 300 NM
  (POLAR ORBIT)

- **USE**

  METEOROLOGICAL AND
  SCIENTIFIC SATELLITES



- **INITIATED**

  1962 (DOD)

- **1st NASA LAUNCH**

  OCT. 1965

- **LAUNCH SITE**

  WTR

- **LAUNCH RATE CAPABILITY**

  8 PER YEAR

NASA SP65-16319
12-8-65

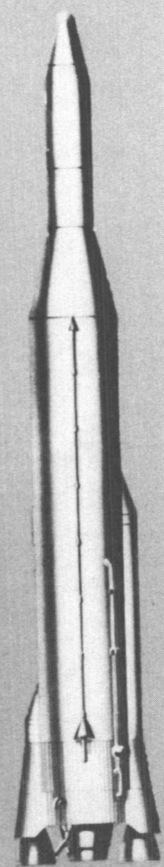
THRUST AUGMENTED THOR AGENA (TAT)

Description: The Thrust Augmented Thor Agena is a two-and-a-half stage rocket consisting of a Thor booster with three solid rocket engines mounted around the periphery of the Thor base, and an Agena as the second stage. The total lift-off thrust is increased to 300,000 pounds by the addition of the solid rocket engines. The solid rockets burn out at approximately 40 seconds after lift-off and are designed to drop away from the basic Thor vehicle at approximately 60 seconds.

Mission Capability: This vehicle combination is capable of placing a 1800-pound payload into a 300 n.m. circular polar orbit.

Schedule: Two TAT Agena vehicles are currently scheduled for launching in 1967. All current TAT-Agena launches are for scientific and applications satellites, which require polar orbits. Commencing in 1965, NASA has used the TAT-Agena launch vehicle to launch the OGO-II on October 14, 1965, the Nimbus II on May 15, 1966, and the Pageos on June 24, 1966.

ATLAS AGENA



- **STAGES**
  - 1ST STAGE - LOX/RP-1 (ATLAS)
  - 2ND STAGE - IRFNA/UDMH (AGENA)
- **MISSION CAPABILITY**
  - 300 N. MI. ORBIT - 6,000 LBS.
  - LUNAR PROBE - 950 LBS.
  - PLANETARY PROBE - 600 LBS. TO MARS
- **USE**
  - LUNAR AND PLANETARY PROBES
  - COMMUNICATIONS SATELLITES
  - SCIENTIFIC SATELLITES
- **INITIATED**
  - MID 1959 (DOD)
- **1ST LAUNCHING**
  - MID 1961 (NASA)
- **LAUNCH RATE CAPABILITY**
  - 10/YR./PAD
- **LAUNCH SITE**
  - ETR - 2 PADS
    (1 PAD AVAILABLE FOR BACK-UP)

NASA S63-299
Rev. 11-17-66

ATLAS AGENA

Description: The Atlas Agena is a two-stage vehicle. The first stage is a Standard model Atlas designed to accept an Agena second stage which uses UDMH and IRFNA as the propellants. This vehicle combination is approximately 91 feet high, exclusive of payload. The Atlas develops 367,000 pounds of thrust at sea level. The Agena second stage thrust is 16,000 pounds.

Mission Capability: The Atlas Agena was employed to launch the Ranger series of hard lunar landing missions and the Mariner planetary probes. It is currently scheduled to launch the Lunar Orbiter series, the Orbiting Astronomical Observatories, the Orbiting Geophysical Observatories, and the Applications Technological Satellites. This vehicle combination can place about 6,000 pounds into a 300 n.m. circular orbit, send over 950 pounds to the Moon, or inject 600 pounds to Mars.

Schedule: Seven Atlas Agena launches are planned for 1967. Seventeen Atlas Agena launches have been completed to date, commencing with Ranger I in 1961.

During CY 1966, four spacecraft were launched by the Atlas Agena from the Eastern Test Range; the first OAO, an OGO, and two Lunar Orbiters. In preparation for launch in early December is the first Applications Technology Satellite.

CENTAUR

- **STAGES**
  - 1st LIQUID
  - 2nd LIQUID (HIGH ENERGY)
- **MISSION CAPABILITY**
  - LUNAR PROBE 2,500 LBS
  - SYNCHRONOUS TRANSFER ORBIT 4,200 LBS.
- **USE**
  - LUNAR AND PLANETARY EXPLORATION
  - OBSERVATORIES
- **INITIATED**
  - LATE 1958
- **1ST LAUNCHING**
  - R&D - MAY 1962
  - OPERATIONAL - 1966
- **LAUNCH RATE CAPABILITY**
  - 6 PER YEAR PER LAUNCH PAD
- **LAUNCH SITE**
  - ETR-2 PADS

NASA S63-671
Rev. 11-17-66

CENTAUR

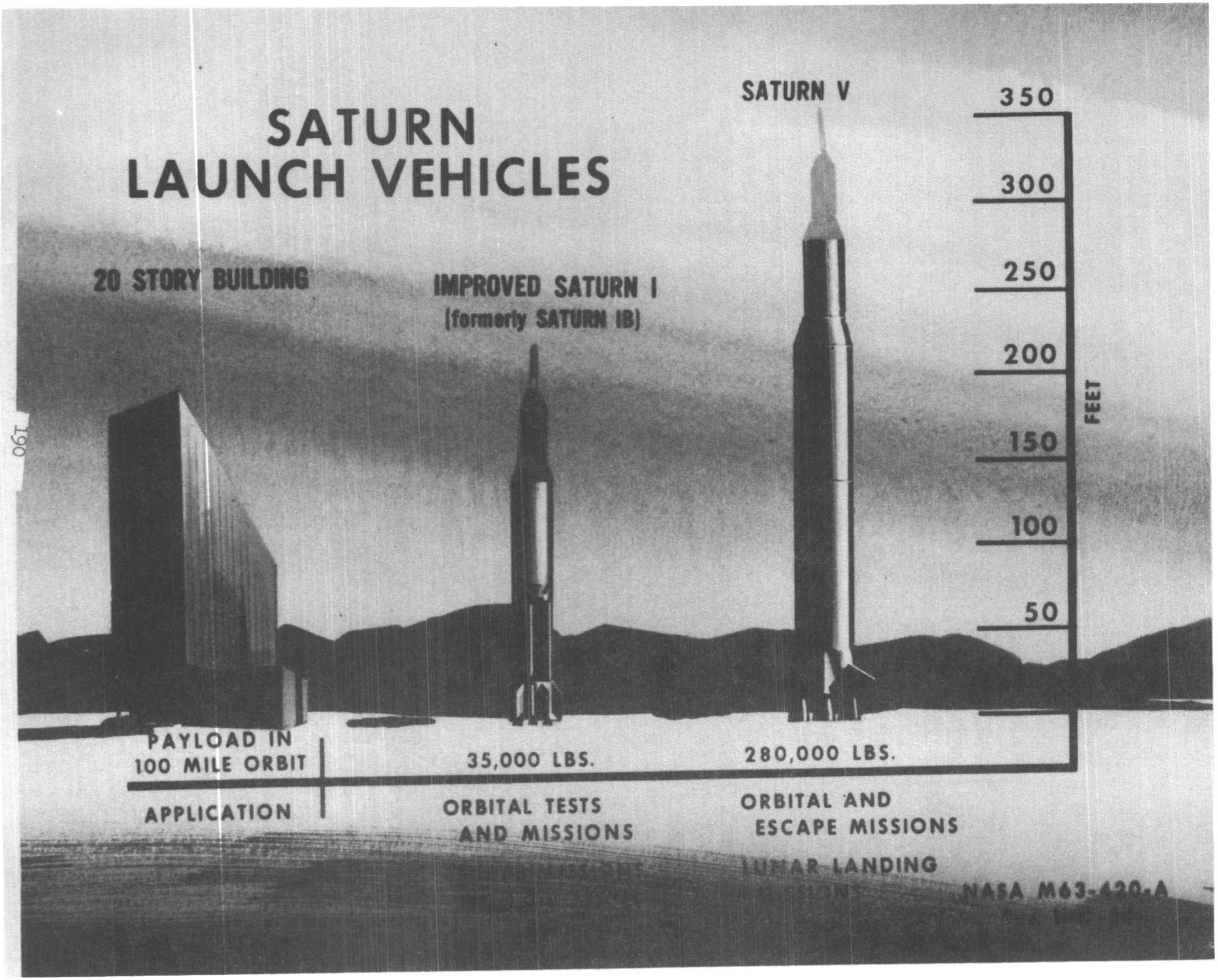
Description: Centaur is a 10 ft. diameter high-energy upper stage powered by two Pratt and Whitney RL 10-A-3 liquid hydrogen-liquid oxygen engines of 15,000 pound thrust each. Centaur uses a modified Atlas as a first stage. This configuration is over 105 feet long and weighs about 300,000 pounds at launch.

Mission Capability: The high-energy propellants used in Centaur give it a payload capability substantially above that of the Atlas Agena. Its performance advantages for high-velocity missions is even more marked. It is used by NASA principally for the Surveyor series of unmanned soft lunar landings, Mariner-Mars missions and other high-energy missions.

Schedule: The first development flight of Centaur took place on May 8, 1962. The vehicle failed during first stage flight, probably due to aerodynamic forces. The fifth launch was unsuccessful because of an Atlas booster failure immediately after lift-off.

The second, third, fourth and sixth development flights were successful. The development test program for direct ascent Surveyor missions was concluded in 1965. The development for the parking orbit ascent was concluded in 1966.

Centaur successfully launched the first Surveyor in May 1966. The Centaur is expected to remain as an operational stage well into the 1970 decade.


SATURN
LAUNCH VEHICLES
20 STORY BUILDING
IMPROVED SATURN I
(formerly SATURN IB)
SATURN V
350
300
250
200
150
100
50
FEET
PAYLOAD IN
100 MILE ORBIT
35,000 LBS.
280,000 LBS.
APPLICATION
ORBITAL TESTS
AND MISSIONS
ORBITAL AND
ESCAPE MISSIONS
LUNAR LANDING
NASA M63-420-A

SATURN V

Description: The Saturn V first stage (S-IC) will be powered by five Rocketdyne F-1 engines, each of which develops 1.5 million pounds of thrust for a total sea level thrust of 7.5 million pounds. The engines will be arranged in a square pattern of four gimballed engines with one fixed engine in the center of the square pattern. The S-IC will have a propellant capacity of approximately 4.5 million pounds consisting of liquid oxygen and hydrocarbon fuel in two tanks, each approximately 33 feet in diameter. The total length will be approximately 138 feet.

The second stage (S-II) will be powered by five J-2 engines developing 200,000 pounds thrust each, for a total vacuum thrust of 1,000,000 pounds. The propellant (liquid oxygen and liquid hydrogen) capacity will be in excess of 900,000 pounds. The second stage will be approximately 33 feet in diameter and approximately 82 feet long.

The third stage (S-IVB) will use one J-2 engine for a total vacuum thrust of 200,000 pounds. It will carry approximately 230,000 pounds of liquid oxygen and liquid hydrogen and will be approximately 22 feet in diameter and 58 feet long.

The instrument unit for the Saturn V comprises the topmost 3 feet of the vehicle, and is basically the same as that for the Improved Saturn I.

Mission Capability: The Saturn V launch vehicle system will have sufficient payload capability to perform manned lunar-landing missions using a single lunar-orbital rendezvous. Also, it will provide a basic vehicle for manned circumlunar and lunar orbit missions, and for automated lunar and planetary explorations. This launch vehicle will have the capability of putting approximately 140 tons (including the S-IVB and instrument unit) in a low Earth orbit and of sending more than 45 tons to the vicinity of the Moon. Prime emphasis will be placed on the Apollo mission. This launch will be used to support the automated Voyager Program to Mars. The full capability of the Saturn V will be utilized to inject 55,000 pounds (two Voyager space vehicles) on a transfer trajectory to Mars.

239-359 O - 66 - 13

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UNIVERSITY PROGRAM

UNIVERSITY PROGRAM

NASA sponsors a wide variety of research in space-related science and technology by universities and non-profit organizations. This research ranges from basic investigations to technological applications, and many of the scientific and technological advances recorded in this report were made possible by university efforts. During Fiscal Year 1966, $128.2 million was obligated to universities, excluding JPL and Apollo Guidance, by all NASA sources. Of this amount $44.7 million was obligated by the Sustaining University Program. The balance of the funds supported project-type research.

Predoctoral Training

In order to help provide a continuing supply of highly trained scientists and engineers, NASA sponsors a Predoctoral Training Program under which grants are made to universities having doctoral programs in space-related sciences and technology. There are now 152 universities participating in the program, located in every state of the Union, and listed below.

The training grants include funds for stipends for predoctoral students, who are selected by the universities. They also include funds for the universities to help strengthen their graduate programs in space-related science and technology.

In September, 1966 some 1,335 predoctoral students began training. Subject to maintaining good academic records, they will be able to continue for three years on a full-time, calendar year basis. With the addition of these 1,335 trainees to those of the previous years, there are now a total of 3,681 enrolled and working toward their doctorate in a space-related discipline. The chart illustrates the disciplines in which the NASA trainees are pursuing their doctorates.

By September, 1966 a total of 334 NASA trainees had received their Ph.D. in this program. Their initial career choices were as follows: 153 went to a university to teach and carry on research; 49 continued on with postdoctoral studies; 95 went to industry; 25 went to a government installation or laboratory, and 12 went to the armed services.

239-359 O - 66 - 14

Adelphi University
Alabama, University of
Alaska, University of
Alfred University
Arizona State University
Arizona, University of
Arkansas, University of
Auburn University
Baylor University
Boston College
Boston University
Brandeis University
Brigham Young University
Brooklyn, Polytechnic Institute of
Brown University
California Institute of Technology
California, University of, at Berkeley
California, University of, at Los Angeles
California, University of, at Riverside
California, University of, at San Diego
California, University of, at Santa Barbara
Carnegie Institute of Technology
Case Institute of Technology
Catholic University of America
Chicago, University of
Cincinnati, University of
Clark University
Clarkson College of Technology
Clemson University
Colorado School of Mines
Colorado State University
Colorado, University of
Columbia University
Connecticut, University of
Cornell University
Dartmouth College
Delaware, University of
Denver, University of
Drexel Institute of Technology
Duke University
Duquesne University

Emory University
Florida State University
Florida, University of
Fordham University
George Washington University
Georgetown University
Georgia Institute of Technology
Georgia, University of
Hawaii, University of
Houston, University of
Howard University
Idaho, University of
Illinois Institute of Technology
Illinois, University of
Indiana University
Iowa State University
Iowa, University of
Johns Hopkins University
Kansas State University
Kansas, University of
Kent State University
Kentucky, University of
Lehigh University
Louisiana State University
Louisville, University of
Lowell Technological Institute
Maine, University of
Marquette University
Maryland, University of
Massachusetts Institute of Technology
Massachusetts, University of
Miami, University of
Michigan State University
Michigan Technological University
Michigan, University of
Minnesota, University of
Mississippi State University
Mississippi, University of
Missouri, University of
Missouri, University of, at Rolla
Montana State University
Montana, University of
Nebraska, University of
Nevada, University of
New Hampshire, University of

New Mexico State University
New Mexico, University of
New York, The City University of
New York, State University of,
  at Buffalo
New York, State University of,
  at Stony Brook
New York University
North Carolina State
  of the University of North Carolina
North Carolina, University of
North Dakota State Unversity
North Dakota, University of
Northeastern University
Northwestern University
Notre Dame, University of
Ohio State University
Ohio University
Oklahoma State University
Oklahoma, University of
Oregon State University
Pennsylvania State University
Pennsylvania, University of
Pittsburgh, University of
Princeton University
Purdue University
Rensselaer Polytechnic Institute
Rhode Island, University of
Rice University
Rochester, University of
Rutgers - The State University
St. Louis University
South Carolina, University of
South Dakota, University of
Southern California, University of
Southern Illinois University
Southern Methodist University
Southern Mississippi, University of
Stanford University
Stevens Institute of Technology
Syracuse University
Temple University
Tennessee, University of

Texas A&M University
Texas Christian University
Texas Technological College
Texas, University of
Toledo, University of
Tufts University
Tulane University
Utah State University
Utah, University of
Vanderbilt University
Vermont, University of
Villanova University
Virginia Polytechnic Institute
Virginia, University of
Washington State University
Washington University (St. Louis)
Washington, University of
Wayne State University
West Virginia University
Western Reserve University
William and Mary, College of
Wisconsin, University of
Worcester Polytechnic Institute
Wyoming, University of
Yale University
Yeshiva University

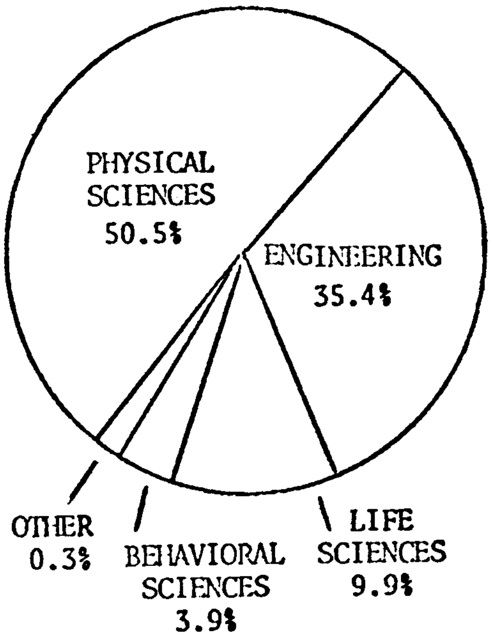
NASA Predoctoral Trainees
School Year 1966-67
Distribution by Discipline

PHYSICAL SCIENCES

	No. of Trainees
Mathematics	432
Chemistry	493
Physics	708
Astronomy	65
Geology & Geophysics	111
Atmospheric Sciences	27
Computer Science	22
	1,858

ENGINEERING

Electrical & Instruments	402
Mechanical	255
Chemical	207
Aeronautics/Astronautics	132
Civil	74
Engineering Mechanics	62
Metallurgical & Materials	71
Engineering & Applied Science	32
Nuclear	36
Industrial	32
	1,303



LIFE SCIENCES

	No. of Trainees
Zoological Sciences	191
Botanical Sciences	63
Biochemistry & Biophysics	50
Microbiology	51
Genetics	9
	364

BEHAVIORAL SCIENCES

Psychology	118
Economics	13
Political Science	11
Sociology	2
Anthropology	1
	145

OTHER

Space Law	1
Business Administration	5
Industrial Management	2
Philosophy of Science	3
	11

TOTAL	3,681

Special Activities

Several special training activities are also supported.

Under NASA's Summer Faculty Fellowship Program, a group of institutes are sponsored jointly by NASA and the universities in the immediate vicinity of NASA Centers. These cooperative endeavors offer the opportunity for approximately 150 faculty members to obtain firsthand research experience by working on current space problems in one of the NASA Research Centers and, concurrently, to participate in seminar activities conducted by the nearby university, or universities.

A small, but imaginative series of Summer Institutes has been developed for undergraduates. These Institutes offer an opportunity for talented undergraduates, chosen on a national basis, to participate in an intensive exploratory program in space science or space technology. During the summer of 1966, three such Institutes were sponsored, each serving about 50 advanced undergraduates.

The NASA Resident Research Associateship Program offers postdoctoral and senior postdoctoral researchers an opportunity to come to a NASA Center for a period of about a year to conduct advanced research on a full-time basis. The researchers are especially qualified individuals, investigating some field of study critical to NASA. There were about 100 such postdoctoral Associates on tenure at eight NASA Centers at the beginning of Fiscal Year 1967. The program is administered for NASA by the National Academy of Sciences.

Research

The fundamental purpose of the Research element of the Sustaining University Program is to extend and enhance participation of university researchers in NASA's programs. By offering universities increased encouragement and opportunities for strengthening their research potential, capabilities, and performance, many of the best university faculty members and scholars have become involved in critical space-related research programs. These programs have developed in an atmosphere which promotes a total university view of NASA's problems.

Through the mechanism of the broadly-based research grant, which provides stable, long-term support, the universities have exercised increased institutional responsibility in the selection of research programs and they have emphasized creativity, growth, and flexibility in fostering multidisciplinary approaches to research work. As a result of the opportunities presented by this Program, many universities have developed strong competence and capabilities in areas of interest to NASA and they have developed curricula and training activities responsive to the new challenges in the space program. Some have begun to establish themselves as regional, and in a few cases national, centers of aeronautical and space research.

An effective channel of communication has been opened between NASA researchers and their university counterparts. The universities have made significant contributions to NASA's immediate research problems and some are beginning to look at our more difficult long-range needs.

During 1965 12 universities were added to the growing list of grantees in this Program, to bring the total to 47 currently active grants. About 940 faculty members and 808 research assistants are involved in approximately 750 specific research investigations in the space science and engineering research being conducted under these grants. As a result of the work done under the 47 grants, 7 of which were only recently initiated, there have been 740 publications.

In keeping with the philosophy of seeking out and identifying new talent, the number of researchers who successfully compete on a national level for individual project support is a meaningful one. To date, some 70 investigations at 21 schools, have received separate funding.

The institutions presently participating in this research element of the Sustaining University Program are:

Adelphi University
Alabama, University of
*Arizona, University of
Brown University
California, University of (Berkeley)
California, University of (Los Angeles)
California Institute of Technology
*Cincinnati, University of
*Colorado State University
Denver, University of
*Drexel Institute of Technology
Duke University
Florida, University of
*George Washington University
Georgia Institute of Technology
Graduate Research Center of the Southwest
*Houston, University of
Kansas, University of
Kansas State University
Louisville, University of
Maine, University of
Maryland, University of
Massachusetts Institute of Technology
*Miami, University of
Minnesota, University of
Missouri, University of
Montana State University
New Mexico State University
*New York University
*Oklahoma, University of
Oklahoma State University
Pennsylvania, University of
Pennsylvania State University
Pittsburgh, University of
Purdue University
*Rice University
*Southern California, University of
Southern Methodist University
*Tennessee, University of
Texas A&M University
Vermont, University of
Virginia, University of
Virginia Polytechnic Institute
Washington University (St. Louis)
West Virginia University
William & Mary, College of
Wisconsin, University of

*New SUP research grantees in Fiscal Year 1966

Research Facilities

The research facilities segment of the Sustaining University Program is concerned with providing adequate laboratory space at those universities which are heavily engaged in scientific and technical activities for NASA. During the five calendar years which have elapsed since the inauguration of the Program, 35 grants have been awarded. Table I shows pertinent information about each award. It should be noted that twenty-one of these structures have already been completed and occupied, while all but four of the rest have passed the design stage. These first completed structures, shown on Table II, represent about 700 thousand square feet of research laboratory space which otherwise would not have been available to the universities for the conduct of aeronautical and space-related research and training. Just these first completed structures will accommodate about 2,000 scientists, engineers, graduate students and others supporting the research effort.

SUMMARY OF UNIVERSITY RESEARCH FACILITIES

INSTITUTION	GROSS AREA (1000 SF)	PER CENT COMPLETION	COST ($ 1000)
RPI	60	100	$ 1,500
STANFORD	15	100	535
CHICAGO	45	100	1,749
IOWA	24	100	610
CALIFORNIA (BERKELEY)	44	100	1,990
HARVARD	5	100	151
MINNESOTA	17	100	542
M.I.T.	75	35	3,000
COLORADO	32	100	792
CALIFORNIA (LOS ANGELES)	69	100	2,000
WISCONSIN	12	50	365
MICHIGAN	56	100	1,436
PITTSBURGH	47	100	1,497
PRINCETON	26	100	625
LOWELL	9	100	237
TEXAS A&M	34	90	1,000
MARYLAND	77	100	1,500
SOUTHERN CALIFORNIA	4	100	160
CORNELL	38	60	1,350
RICE	68	85	1,600
PURDUE	5	100	840
WASHINGTON (ST. LOUIS)	25	100	600
NEW YORK	13	100	582
GEORGIA TECH	51	100	1,000
ARIZONA	51	100	1,200
ILLINOIS	51	60	1,125
P.I.B.	16	100	632
CASE INST. OF TECH.	69	DESIGN	2,226
ROCHESTER	35	DESIGN	1,000
FLORIDA	53	1	1,190
MINNESOTA	70	1	2,500
DENVER	41	1	900
STANFORD	65	DESIGN	2,080
WISCONSIN	58	BID	1,700
WASHINGTON	40	DESIGN	1,500
TOTAL	1,400		$ 41,714

Table I

COMPLETED RESEARCH FACILITIES

● RENSSELAER POLYTECHNIC INSTITUTE	MATERIALS RESEARCH CENTER
● STANFORD UNIVERSITY	EXOBIOLOGY LABORATORIES
● UNIVERSITY OF CHICAGO	LABORATORY FOR SPACE SCIENCES
● UNIVERSITY OF IOWA	PHYSICS AND MATHEMATICS BUILDING
● UNIVERSITY OF CALIFORNIA (BERKELEY)	SPACE SCIENCES LABORATORY
● HARVARD UNIVERSITY	BIOMEDICAL LABORATORIES
● UNIVERSITY OF MINNESOTA	PHYSICS LABORATORIES
● UNIVERSITY OF COLORADO	LABORATORY FOR SPACE PHYSICS
● UNIVERSITY OF CALIFORNIA LOS ANGELES	SPACE SCIENCES LABORATORIES
● UNIVERSITY OF MICHIGAN	SPACE RESEARCH LABORATORY
● UNIVERSITY OF PITTSBURGH	SPACE RESEARCH AND COORDINATION CENTER
● PRINCETON UNIVERSITY	PROPULSION RESEARCH LABORATORIES
● LOWELL OBSERVATORY	PLANETARY RESEARCH CENTER
● UNIVERSITY OF MARYLAND	SPACE SCIENCES CENTER
● UNIVERSITY OF SOUTHERN CALIFORNIA	HUMAN CENTRIFUGE
● PURDUE UNIVERSITY	ROCKET TEST FIRING FACILITIES
● WASHINGTON UNIVERSITY (ST. LOUIS)	RESEARCH LABORATORY OF PHYSICS
● NEW YORK UNIVERSITY	AEROSPACE SCIENCES BUILDING
● GEORGIA INSTITUTE OF TECHNOLOGY	SPACE SCIENCES AND TECHNOLOGY CENTER
● UNIVERSITY OF ARIZONA	SPACE SCIENCES BUILDING
● POLYTECHNIC INSTITUTE OF BROOKLYN	AEROSPACE RESEARCH LABORATORY

Table II

COSTS OF LAUNCHED SPACECRAFT

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COSTS OF LAUNCHED SPACECRAFT (MILLIONS OF DOLLARS)

Orbiting Astronomical Observatories

Spacecraft	(10)	$ 536.9
Atlas Agena	(10)	107.2
Total		$ 644.1

Unit cost $64.4 million.

Orbiting Geophysical Observatories

Spacecraft	(6)	$ 219.1
Atlas Agena	(3)	27.4
Thor Agena	(3)	19.7
Total		$ 266.2

Unit cost $44.37 million.

Orbiting Solar Observatories

Spacecraft	(9)	$ 94.8
Delta Dev. Vehicle	(1)	2.5
Delta Proc. Vehicle	(8)	22.4
Total		$ 119.7

Unit cost $13.3 million.

Beacon Explorer

Spacecraft	(3)	$ 5.4
Scout	(2)	3.0
Delta	(1)	2.9
Total		$ 11.3

Unit cost $3.76 million.

Atmosphere Explorers

Spacecraft	(2)	$ 6.8
Delta	(2)	5.9
Total		$ 12.7

Unit cost $6.35 million.

Ionosphere Explorers

Spacecraft	(2)	$ 3.0
Scout	(1)	1.5
Total		$ 4.5

Unit cost $4.5 million.

Air Density/Injun Explorers

Spacecraft	(3)	$ 4.6
Scout	(3)	4.4
Total		$ 9.0

Unit cost $3.0 million.

Radio Astronomy Explorers

Spacecraft	(4)	$ 30.9
Delta	(4)	14.0
Total		$ 44.9

Unit cost $11.22 million.

Owl Explorers

Spacecraft	(2)	$ 4.2
Scout	(2)	2.9
Total		$ 7.1

Unit cost $3.56 million.

International Satellites

Spacecraft	(17)	$ 25.6
Scouts	(12)	18.7
Delta Dev.	(1)	2.5
Delta Proc.	(3)	10.3
Thor Agena	(2)	20.3
Total		$ 77.4

Unit cost $4.55 million

Does not include spacecraft cost funded by International Groups.

Energetic Particles Explorers

Spacecraft	(4)	$ 7.4
Delta Dev.	(2)	5.5
Delta Proc.	(2)	5.8
Total		$ 18.7

Unit cost $4.7 million.

Interplanetary Monitoring Probes

Spacecraft	(10)	$ 56.0
Delta	(10)	33.3
Total		$ 89.3

Unit cost $8.93 million.

Pioneer

Spacecraft	(5)	$ 64.1
Delta	(5)	17.5
Total		$ 81.6

Unit cost $16.3 million.

Small Standard Satellite

Spacecraft	(4)	$ 18.4
Scout	(4)	5.6
Total		$ 24.0

Unit cost $6.0 million.

X-Ray Explorer

Spacecraft	(1)	$ 5.0
Scout	(1)	1.5
Total		$ 6.5

Unit cost $6.5 million.

Pilgrim Explorer

Spacecraft	(1)	$ 4.3
Scout	(1)	1.4
Total		$ 5.7

Unit cost $5.7 million.

Lunar Orbiter

Spacecraft	(5)	$ 174.6
Atlas Agena	(5)	42.3
Total		$ 216.9

Unit cost $43.38 million.

Surveyor Lander

Spacecraft	(7)	$ 488.9
Centaur	(7)	103.3
Total		$ 592.2

Unit cost $84.6 million.

Voyager

Spacecraft	(4)	$1,800.7
Saturn V	(2)	230.0
Total		$2,030.7

Unit cost $507.7 million.

Mariner Venus 1967

Spacecraft	(1)	$ 26.5
Atlas Agena	(1)	8.9
Total		$ 35.4

Unit cost $35.4 million.

Mariner Mars

Spacecraft	(4)	$ 303.1	
Mariner-Mars 1969	(2)		(107
Mariner-Mars 1971	(2)		(196
Centaur	(4)	40.1	
Total		$ 343.2	

Unit cost $85.8 million.

Applications Technology Satellites

Spacecraft	(7)	$ 166.0
Atlas Agena	(5)	40.0
Atlas Centaur	(2)	20.0
Total		$ 226.0

Unit cost $32.3 million.

Geodetic Explorers

Spacecraft	(6)	(5) Active	$ 34.1
		(1) Passive	
Delta	(5)		17.5
Thor-Agena	(1)		7.0
Total			$ 58.6

Unit cost $9.77 million.

TIROS M

Spacecraft	(1)	$ 17.9*
Delta	(1)	3.5
Total		$ 21.4

Unit cost $21.4 million.
*Includes $3.1 million for ground equipment and sensors funded by ESSA.

Voice/TV Broadcast Satellite

Spacecraft	(2)	$ 100.0
Atlas Centaur	(2)	20.0
Total		$ 120.0

Unit cost $60.0 million.

Nimbus

Spacecraft	(4)	$ 207.5
Thor Agena	(4)	34.2
Total		$ 241.7

Unit cost $60.4 million.

Nimbus Followon

Spacecraft	(4)	$ 140.0
TAT Agena	(4)	26.8
Total		$ 166.8

Unit cost $41.7 million.

Biosatellite

Spacecraft	(6)	$ 136.5
Delta	(6)	21.0
Total		$ 157.5

Unit cost $26.25 million.

Sunblazer

Spacecraft	(5)	$ 9.5
Scout	(5)	7.5
Total		$ 17.0

Unit cost $3.4 million.

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